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CONTENTS

Volume XII

THE WHEATS OF BIHAR AND ORISSA.

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I. INTRODUCTION.

SINCE the publication of the botanical classification[1] of the wheats of Bengal, a new Indian Province, Bihar and Orissa, has been created. In this administrative area are to be found practically the whole of the wheat growing tracts of old Bengal. The wheats of Bengal have become to a large extent the wheats of Bihar and Orissa.

The preliminary classification, published in 1909, was only carried as far as the botanical variety. Since that time, the various agricultural types (unit species) which make up these varieties have been grown for some years in pure culture at Pusa and have been studied in considerable detail. The present paper deals with 122 of these agricultural types of common wheat (*Triticum vulgare* Vill.) belonging to twelve botanical varieties, three of which do not appear to have been described.

[1] *Wheat in India*, 1909, p. 196.

The material from which these 122 agricultural types were obtained was collected at harvest time mainly from cultivators' fields in the most important wheat growing tracts of Bihar, north and south of the Ganges. The ripe ears were first classified according to the botanical variety and were then sown separately, side by side, for several years. As soon as sufficient seed was obtained for sowing small plots (about 10 feet wide and 30 feet long), it was noticed that the finer characters (such as the time of coming into ear, the characters of the ears and leaves at the time of flowering, the power of tillering, the vegetative vigour at the time of pollination, the resistance to rust and the length and strength of straw) became much more definite and distinct than when the cultures were grown in single lines next to next. What may be termed the massed habit came into operation the moment the cultures were grown in oblong plots. In the early morning, when the plants are fully turgid and when the foliage and ears are illuminated by the slanting rays of the sun, differences which cannot be detected a few hours later stand out clearly. Equally definite is the behaviour of the cultures towards the three rusts[1] which occur at Pusa. In the same botanical variety, agricultural types occurred which differed more in their degree of susceptibility to rust than in any other character. In several instances, two types—almost identical in field characters—exhibited great differences in resistance to brown rust (*Puccinia triticina* Ericks.).

By taking advantage of the time of ripening, of the vegetative characters at the time of flowering and of the degree of resistance to the various rusts, it is not difficult to classify the unit species within the botanical variety even when the number of these types is very great. While the finer differences, such as the tone of colour of the leaves and of the ears at the time of pollination, are inherited exactly like the more important botanical characters (the presence or absence of awns, colour of the chaff and grain), nevertheless the degree of their expression depends on the way the crop is grown and also on the season. If no particular care is taken in raising the cultures and if the season is adverse, the fine vegetative differences do not stand out sharply and types really different in the field can then only be distinguished by the degree of their resistance to brown, yellow or black rust.

Ordinarily, systematic botany deals with nothing below the variety and does not recognize the differences between the unit species which make up these varieties. While such a point of view is obviously essential in dealing with herbarium specimens and with the large groups of plants belonging to genera

[1] The three species of rust which attack wheat at Pusa, in the order of their appearance, are: brown rust (*Puccinia triticina* Eriks.), yellow rust (*P. glumarum* Eriks. & Henn.), and black rust (*Puccinia graminis* Pers.)

and orders, it does not go far enough for the plant breeder who has to study the elementary species themselves in the field from sowing time to harvest and to ascertain their potentialities as parents or as the starting point in schemes of seed distribution. By employing the methods of the systematist, however, it is possible to classify and to distinguish clearly the unit species which make up the variety. Such an exercise is an essential preliminary in the study of cultivated crops, in the methods of selection and also in the creation of new forms by hybridization. It is mainly to emphasize the importance of systematic botany in the training of the plant breeders of the future that we have recorded this classification of the unit species which compose the varieties of the common wheats met with in Bihar. Such a collection of unit species serves a double purpose. In the first place, they are of the greatest use in bringing home to the student the great complexity of the Linnean species and the vast amount of preliminary work which is essential in every crop before research proper can be undertaken with any hope of success. In the second place, they form the raw material for the plant breeder and the mycologist and so their proper maintenance becomes an important part of the work of research institutes which deal with crops.

As the intensive study of cultivated plants develops all over the world, an increasing amount of accurate information on the composition of the botanical variety will become available. The work already published indicates that the number of different unit species in existence in each botanical variety is certain to be very great and may, in some cases, run into hundreds.[1] It is important from the point of view of the future of plant breeding that these unit species should be maintained and that the material should be readily available to workers in all countries. It is only in this way that the vast possibilities in the improvement of cultivated crops can be realized. Perhaps the easiest method of maintaining these collections will be for the Central Research Institutes, maintained by Government in the various countries, to undertake the work and for each to concentrate on a few important corps. In this way a beginning could be made in the ultimate classification of cultivated plants with the resources now available. If, as is likely, the free interchange of unit species proves to be of importance in the rapid production of improved seed for general distribution, the extension of this work will then be only a question of time and of mutual arrangement among the workers themselves.

[1] That many of the varieties of common wheat, *Triticum vulgare* Vill., comprise a very large number of unit species is indicated by the work of Vavilov and his colleagues in Russia The details of this work are in the press but the general results are summed up in a paper on the law of homologous series in variation in the *Jour. of Genetics,* XII, 1922, p. 47.

II. CLASSIFICATION OF THE WHEATS OF BIHAR AND ORISSA.

The wheats of Bihar are characterized by weak straw, poor vegetative growth and early maturity. Almost all are bearded with smooth chaff and short, rounded grains. Three of the varieties possess blackish chaff on a red or white ground with black awns. In the size and shape of the grain and in the frequent occurredce of black awns, these wheats are sharply distinguished from the types met with in the United Provinces and the Punjab. Among Indian wheats they most closely resemble the forms often found in the Himalayas and on the Western Frontier. Some of the types are very resistant to brown, yellow and black rusts, particularly those belonging to the new variety *nigricans*. High grain quality, comparable with that of Manitoba wheats, also occurs among these types as is shown by the results of the milling and baking tests[1] carried out in 1909 by Mr. A. E. Humphries. So far as we have investigated the matter, some of these wheats appear to possess greater strength than any of the other indigenous types we have examined. It is easy to understand that in a damp climate such as that of Bihar which favours rust epidemics, natural selection would operate in eliminating types susceptible to disease and in preserving the more resistant forms. The occurrence of stronger wheats in this tract than in the rest of the plains is, however, not so easily explained. None of the types are likely to prove of use for distribution to the cultivators on account of their weak vegetative characters and their inability successfully to respond to intensive cultivation. They may, however, prove to be of the very greatest use in plant breeding in providing early maturing parents with great resistance to rust combined with short straw and grain qualities above the average. It is possible that one of these unit species has already been made use of in the production of an improved wheat. Marquis[2], the celebrated Canadian variety, which covers millions of acres in North America, was obtained by crossing Red Fife with one of the wheats found in Hard Red Calcutta. This is the most successful wheat variety hitherto evolved by the plant breeder.

In the classification of the varieties we have followed the system devised by Koernicke with the addition of three new varieties with blackish chaff and black awns not included in *Die Arten und Varietaten des Getreides* or in the subsequent literature on this subject. As far as our investigations have gone, these new varieties are only met with in Bihar and Orissa.

In distinguishing the unit species which constitute the varieties, we have made full use of all the vegetative characters at the time of pollination. The

[1] *Bulletin* 17, *Agri. Research Institute, Pusa*, 1910, p. 9.

Buller, A. H. R. *Essays on wheat*, New York, 1919.

time of coming into ear enables the types to be divided into classes such as very early, early, intermediate, late and very late. The length of the straw when pollination is completed serves to distinguish short, intermediate and tall forms. The tone of colour of the ears and of the foliage together with the presence or absence of bloom are most useful characters at the time of flowering as well as the length and breadth of the leaves and the manner in which they are disposed (vertical or drooping). From the time of flowering to harvest, the types often differ markedly in the amount of leaf rust. The numbers for stem rust as well as the standing power of the types can best be distinguished at harvest time. The period when it is easiest to distinguish the unit species is, however, during the time when the flowers are fertilized at the end of the vegetative period.

In order to record from year to year the degree of susceptibility of the various unit species to the three common rusts, we have employed Eriksson's notation in which the increasing amount of infection is represented by the numbers 1, 2, 3 and 4. When traces only of rust could be found with difficulty, this is indicated by the words *slight* or *very slight*. The entire absence of any rust is indicated by the symbol zero.

The records of rust-resistance vary to some extent from year to year. This is inevitable on account of the natural incidence of the many factors on which an epidemic depends. Besides the inherent resistance of the unit species themselves and the well known influence of such factors as humidity and temperature on the spread of the fungus, the various external factors also affect the resistance of the host. A time comes when conditions are optimum for the rust and when the resistance of the host is near its lowest point. Maximum rust numbers are then obtained. If the season favours the host, lower numbers are likely to be the rule. There is, however, a further complication, namely, the period in the life-history of the host when the rust attack takes place. When this occurs before the ripening process begins, the rust has time to accomplish the maximum amount of damage. If the attack takes place very late in the season when ripening is nearly completed, the crop may be only slightly affected. As a collection of unit species contains very early, early, late and very late types, it is easy to see that in certain years some of the groups are favoured while others are severely handicapped. As a rule, the early types tend to escape while the late ones are the most seriously affected. These considerations explain why the numbers for any particular rust vary from year to year and why it is necessary to keep under close observation for some years any types which appear to be more resistant than the average. It is only when a particular unit species escapes rust

almost entirely for a series of years that we can say with any confidence that it is really rust resistant. As an example of the kind of influence which the season exerts on the degree of infection, the black rust numbers obtained at Pusa in two seasons in the case of two groups of unit species (one rust resistant, the other susceptible) may be quoted.

TABLE I.

Seasonal variation in resistance to black rust.

(*a*) var. *nigricans* (resistant).

Type numbtr	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1916	1	1	1	1	1	1	v.s.	1	v. s.	1	1	1	1	v.s.	v.s.	1	2	v.s.	1	1
1921	s.	1	s.	1	1	1	s.	1	v.s.	1	0	s.	1	1	1	1	s.	1	s.	1

v.s. = very slight. s. = slight. 0 = black rust absent.

(*b*) var. *græcum* Kcke. (susceptible).

Type number	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1915	3	2	2	3	3	3	2	4	2	3	3	3	3	3	1	2	3
1921	2	1	1	1	2	1	2	2	1	2	1	2	2	2	2	2	3

TRITICUM VULGARE VILL. COMMON WHEATS.

Ears bearded or beardless; outer glumes not keeled to the base; straw hollow; grain neither very long nor round.

I. Ears beardless (short tips).

1. Glumes smooth.

A. Glumes white.

(*a*) Grain white.

var. *albidum* Al.

Types 1–4.

(*b*) Grain red.

var. *lutescens* Al.

Type 5.

B. Glumes red.
(*a*) Grain white.
var. *alborubrum* Kcke.
Types 6–9.
(*b*) Grain red.
var. *milturum* Al.
Types 10–12.

II. Ears bearded.
1. Glumes smooth.
A. Glumes white.
(*a*) Grain white.
var. *græcum* Kcke.
Types 13–29.
(*b*) Grain red.
var. *erythrospermum* Kcke.
Types 30–57.

B. Glumes red.
(*a*) Grain white.
var. *erythroleucon* Kcke.
Types 58–71.
(*b*) Grain red.
var. *ferrugineum* Al.
Types 72–80.

C. Glumes black on a white ground, awns black.
(*a*) Grain red.
var. *nigricans*.
Types 81–100.

D. Glumes black on a red ground, awns black.
(*a*) Grain white.
var. *indicum*.
Types 101–109.
(*b*) Grain red.
var. *bengalensis*.
Types 110–121.

2. Glumes felted.
A. Glumes white.
(*a*) Grain white.
var. *meridonale* Kcke.
Type 122.

In the above scheme, the distinction between bearded and beardless wheats is the one in common use. In reality, however, true beardless wheats possess no awns of any kind while there are at least two different kinds of tips which are commonly grouped among the beardless forms. These we have described in a previous paper[1] as *short tips* and *long tips*. When these are crossed, bearded, intermediates and true beardless are produced in the 9 : 3 : 3 : 1 ratio. Strictly speaking, the so-called beardless wheats will have to be broken up into at least three classes and the ordinary schemes of classification will have to be revised. The beardless wheats of Bihar all appear to possess short tips. Complete proof of this point can, however, only be obtained by employing these unit species as parents.

Description of Unit Species.

var. *albidum* Al.

Ears beardless (short tips), glumes smooth white, grain white.

This variety is represented by four agricultural types all of which are susceptible to rust and are characterized by weak straw. The critical observations on the field characters and on the incidence of rust were made in 1915.

1. Early.

No. 1. Intermediate in height ; ears very light green ; leaves somewhat drooping, light green. Brown rust 3, yellow rust 4, black rust 3. Straw very weak.

2. Late.

No. 2. Short ; ears dark green with much bloom ; leaves erect, dark green. Brown rust 3, yellow rust 3, black rust 3. Straw weak.

No. 3. Short ; ears dark green with much bloom ; leaves erect, dark green. Brown rust 3, yellow rust 2, black rust 1. Straw very weak.

No. 4. Short, tillers well ; ears dark green with much bloom ; leaves erect, dark green. Brown rust 2, yellow rust 1, black rust 1. Straw weak.

var. *lutescens* Al.

Ears beardless (short tips), glumes smooth white, grain red.

This variety is represented by a single agricultural type which is characterized by susceptibility to rust and by rather weak straw.

No. 5. Somewhat early, short ; ears dark green with a bluish tinge and much bloom ; leaves erect, somewhat dark green. Brown rust 3, yellow rust 3, black rust 2. Straw rather weak.

[1] *Mem. of the Dept. of Agri. in India (Botanical Series)*, Vol. VII, 1915, p. 273.

var. *alborubrum* Kcke.

Ears beardless (short tips), glumes smooth red, grain white.

This variety is represented by four agricultural types which fall into three groups according to the time of maturity. With one exception (No. 6), all are characterized by susceptibility to rust and by very weak straw. One of the original pure line cultures was rejected on account of uneven growth following natural cross-fertilization. The observations on which the classification is drawn up were made in 1915.

1. Early.

No. 6. Tall, vigorous; ears very light bright green; leaves drooping, light green. Brown rust 2, yellow rust 1, black rust 1. Straw very weak.

No. 7. Tall, vigorous; ears light green with much bloom; leaves drooping, light green. Brown rust 2, yellow rust 2, black rust 2. Straw very weak.

2. Intermediate in time of maturity.

No. 8. Tall; ears somewhat light green with much bloom; leaves slightly drooping, somewhat light green. Brown rust 3, yellow rust 2, black rust 1. Straw very weak.

3. Late.

No. 9. Intermediate in height; ears dark green with moderate bloom; leaves broad, erect, dark green. Brown rust 3, yellow rust 3, black rust 2. Straw very weak.

var. *milturum* Al.

Ears beardless (short tips), glumes smooth red, grain red.

This variety is represented by three agricultural types which differ considerably in time of maturity. They are all characterized by susceptibility to rust attack and weak straw.

1. Early.

No. 10. Tall, vigorous; ears light green with much bloom; leaves erect, dark green. Brown rust 3, yellow rust 3, black rust 3. Straw very weak.

2. Intermediate in time of maturity.

No. 11. Intermediate in height; ears dark green with moderate bloom; leaves erect, dark green. Brown rust 3, yellow rust 2, black rust 3. Straw very weak.

3. Late.

No. 12. Intermediate in height; ears dark green with moderate bloom; leaves erect, dark bluish green. Brown rust 3, yellow rust 2, black rust 3. Straw weak.

var. *græcum* Kcke.

Ears bearded, glumes smooth white, grain white.

This variety is represented by seventeen agricultural types which fall into three groups according to the time of maturity. The observations on which the classification is based were made in 1915.

1. Early.

No. 13. Very early, short weak; ears dull green; leaves narrow and very drooping, somewhat light bluish green with much bloom. Brown rust 2, yellow rust 4, black rust 3. Straw very weak.

No. 14. Intermediate in height, vigorous; ears dull green; leaves erect, broad, medium green with moderate bloom. Brown rust 4, yellow rust 3, black rust 2. Straw very weak.

No. 15. Intermediate in height, weak; ears dull green; leaves erect, broad, somewhat light green with moderate bloom. Brown rust 3, yellow rust 3, black rust 2. Straw very weak.

Nos. 14 and 15 are nearly alike in the field but are not identical. No 14 is more vigorous and has darker foliage than No. 15 and is more susceptible to brown rust.

No. 16. Intermediate in height, vigorous; ears light green; leaves slightly drooping, light green with much bloom. Brown rust 3, yellow rust 2, black rust 3. Straw very weak.

2. Intermediate in maturity.

No. 17. Intermediate in height, weak; ears light green; leaves slightly drooping, dark green with much bloom. Brown rust 3, yellow rust 4, black rust 3. Straw very weak.

No. 18. Intermediate in height; ears light green; leaves erect, light green, with slight bloom. Brown rust 2, yellow rust 2, black rust 3. Straw weak.

No. 19. Tall, vigorous; ears light green; leaves slightly drooping, light green with very little bloom. Brown rust 1, yellow rust 1, black rust 2. Straw weak.

No. 20. Tall, vigorous; ears light green; leaves broad, slightly drooping, dark green with moderate bloom. Brown rust 1, yellow rust 1, black rust 4. Straw weak.

No. 21. Very tall; ears somewhat dark green; leaves erect, dark green with much bloom. Brown rust 3, yellow rust 1, black rust 2. Straw fairly strong. This culture, as regards the colour of the green ears, forms a connecting link with the next four types (Nos. 22, 23, 24 and 25).

No. 22. Tall, weak; ears dark green; leaves drooping, somewhat dark green with much bloom. Brown rust 4, yellow rust 3, black rust 3. Straw very weak.

No. 23. Tall, weak; ears dark green; leaves drooping, light green with much bloom. Brown rust 3, yellow rust 3, black rust 3. Straw very weak.

No. 24. Tall, vigorous; ears dark green; leaves slightly drooping, somewhat light green with much bloom. Brown rust 2, yellow rust 3, black rust 3. Straw very weak.

No. 25. Tall, vigorous; ears dark green; leaves drooping, dark green with much bloom. Brown rust 4, yellow rust 4, black rust 3. Straw very weak.

3. Late (the four cultures ripen in the following order—29, 26, 28, 27).

No. 26. Tall, very late; ears somewhat dark green; leaves erect, somewhat dark green with much bloom. Brown rust 2, yellow rust 3, black rust 3. Straw weak.

No. 27. Tall; ears light green, leaves somewhat light green with slight bloom. Brown rust 1, yellow rust 1, black rust 1. Straw fairly strong.

No. 28. Tall; ears very light green; leaves erect, somewhat light green with very slight bloom. Brown rust 2, yellow rust 1, black rust 2. Straw somewhat weak.

No. 29. Tall; ears light green; leaves erect (more so than 28), dark green with very slight bloom. Brown rust 2, yellow rust 1 black rust 3. Straw fairly strong.

Nos. 28 and 29 are nearly alike and differ only in the colour of the ears, in the colour and set of the leaves, in resistance to black rust and in time of maturity.

var. *erythrospermum* Kcke.

Ears bearded, glumes smooth white, grain red.

This variety comprises twenty-eight agricultural types which fall into four classes according to time of maturity. The observations on which this classification is based were made in 1916.

1. Very early.

No. 30. Intermediate in height, strong; ears very light bright green; leaves drooping, light green. Brown rust 1, black rust 2. Straw weak.

No. 31. Short; ears dull light green; leaves erect, dark green. Brown rust 4, black rust 4. Straw weak.

No. 32. Short, rather weak; ears dull dark green; leaves erect, dark green. Brown rust 3, black rust 4. Straw weak.

No. 33. Short, weak; ears dark green; leaves erect, dark green. Brown rust 4, black rust 4. Straw weak.

Nos. 32 and 33 closely resemble each other in the field but are not identical. No. 32 is slightly taller and more resistant to brown rust than No. 33 and also has lighter ears than No. 33.

2. Early.

No. 34. Tall; ears somewhat dull light green; leaves erect, light green. Brown rust 1, black rust 2. Straw weak.

No. 35. Tall; ears somewhat dull light green; leaves erect, broad, somewhat light green. Brown rust 1, black rust 2. Straw weak.

No. 36. Intermediate in height, vigorous; ears light bright green; leaves erect, very dark green. Brown rust 1, black rust 2. Straw fairly strong.

No. 37. Tall; ears light green (lighter than No. 38) ripening to a bright tone; leaves erect, broad, dark green. Brown rust 1, black rust 2. Straw weak.

No. 38. Tall; ears light green (darker than No. 37) ripening to a dull tone; leaves erect, broad, dark green. Brown rust 0, black rust 2. Straw somewhat weak.

Nos. 37 and 38 closely resemble each other and only differ in the tone of colour of the ripe ears, in the strength of straw and in resistance to brown rust. Nos. 34, 35, 36, 37 and 38 are all tall and form a natural subdivision of the early types.

No. 39. Intermediate in height, weak; ears dull dark green; leaves erect, light green. Brown rust 1, black rust 3. Straw weak.

No. 40. Tall, weak; ears dull dark green; leaves erect, somewhat light green. Brown rust 1, black rust 3. Straw weak.

No. 41. Tall, weak; ears light green, ripening to a dull tone; leaves erect, very light green (lighter than No. 39). Brown rust 1, black rust 3. Straw weak.

No. 42. Short, weak; ears dull dark green; leaves erect, dark green. Brown rust 2, black rust 3. Straw weak.

No. 43. Short, weak; ears dull dark green; leaves somewhat light green. Brown rust 3, black rust 4. Straw weak.

No. 44. Short; ears somewhat light green, ripening to a dull tone; leaves erect, somewhat light green. Brown rust 1, black rust 3. Straw weak.

No. 45. Intermediate in height, weak; ears dark green, ripening to a dull tone; leaves erect, dark green. Brown rust 1, black rust 4. Straw weak.

3. Late.

No. 46. Intermediate in height, strong; ears dark green, ripening to a somewhat bright tone; leaves erect, broad, dark green. Brown rust 1, black rust 2. Straw fairly strong.

No. 47. Intermediate in height, strong; ears somewhat light bright green; leaves erect, dark green. Brown rust 0, black rust slight. Straw strong.

No. 48. Intermediate in height; ears dark green ripening to a dull tone; leaves erect, somewhat light green. Brown rust 2, black rust 4. Straw very weak.

No. 49. Intermediate in height; ears dark bluish green ripening to a dull tone; leaves erect, dark bluish green. Brown rust 0, black rust 2. Straw fairly strong.

No. 50. Intermediate in height, somewhat weak; ears dull dark green; leaves erect, somewhat light green. Brown rust 1, black rust 3. Straw very weak.

No. 51. Intermediate in height, somewhat weak; ears somewhat light green; leaves erect, dark green. Brown rust 1, black rust 2. Straw strong.

No. 52. Intermediate in height, weak; ears dull dark green; leaves erect, somewhat dark green. Brown rust 0, black rust 2. Straw strong.

4. Very late.

No. 53. Short; ears somewhat light bright green; leaves erect, very dark green. Brown rust 1, black rust 2. Straw somewhat weak.

No. 54. Intermediate in height; ears dark green; leaves erect, dark bluish green. Brown rust 2, yellow rust 1, black rust 4. Straw weak.

1. Very early.

No. 30. Intermediate in height, strong ; ears very light bright green ; leaves drooping, light green. Brown rust 1, black rust 2. Straw weak.

No. 31. Short ; ears dull light green ; leaves erect, dark green. Brown rust 4, black rust 4. Straw weak.

No. 32. Short, rather weak ; ears dull dark green ; leaves erect, dark green. Brown rust 3, black rust 4. Straw weak.

No. 33. Short, weak ; ears dark green ; leaves erect, dark green. Brown rust 4, black rust 4. Straw weak.

Nos. 32 and 33 closely resemble each other in the field but are not identical. No. 32 is slightly taller and more resistant to brown rust than No. 33 and also has lighter ears than No. 33.

2. Early.

No. 34. Tall ; ears somewhat dull light green ; leaves erect, light green. Brown rust 1, black rust 2. Straw weak.

No. 35. Tall ; ears somewhat dull light green ; leaves erect, broad, somewhat light green. Brown rust 1, black rust 2. Straw weak.

No. 36. Intermediate in height, vigorous ; ears light bright green ; leaves erect, very dark green. Brown rust 1, black rust 2. Straw fairly strong.

No. 37. Tall ; ears light green (lighter than No. 38) ripening to a bright tone ; leaves erect, broad, dark green. Brown rust 1, black rust 2. Straw weak.

No. 38. Tall ; ears light green (darker than No. 37) ripening to a dull tone ; leaves erect, broad, dark green. Brown rust 0, black rust 2. Straw somewhat weak.

Nos. 37 and 38 closely resemble each other and only differ in the tone of colour of the ripe ears, in the strength of straw and in resistance to brown rust. Nos. 34, 35, 36, 37 and 38 are all tall and form a natural subdivision of the early types.

No. 39. Intermediate in height, weak ; ears dull dark green ; leaves erect, light green. Brown rust 1, black rust 3. Straw weak.

No. 40. Tall, weak ; ears dull dark green ; leaves erect, somewhat light green. Brown rust 1, black rust 3. Straw weak.

No. 41. Tall, weak ; ears light green, ripening to a dull tone ; leaves erect, very light green (lighter than No. 39). Brown rust 1, black rust 3. Straw weak.

No. 42. Short, weak; ears dull dark green; leaves erect, dark green. Brown rust 2, black rust 3. Straw weak.

No. 43. Short, weak; ears dull dark green; leaves somewhat light green. Brown rust 3, black rust 4. Straw weak.

No. 44. Short; ears somewhat light green, ripening to a dull tone; leaves erect, somewhat light green. Brown rust 1, black rust 3. Straw weak.

No. 45. Intermediate in height, weak; ears dark green, ripening to a dull tone; leaves erect, dark green. Brown rust 1, black rust 4. Straw weak.

3. Late.

No. 46. Intermediate in height, strong; ears dark green, ripening to a somewhat bright tone; leaves erect, broad, dark green. Brown rust 1, black rust 2. Straw fairly strong.

No. 47. Intermediate in height, strong; ears somewhat light bright green; leaves erect, dark green. Brown rust 0, black rust slight. Straw strong.

No. 48. Intermediate in height; ears dark green ripening to a dull tone; leaves erect, somewhat light green. Brown rust 2, black rust 4. Straw very weak.

No. 49. Intermediate in height; ears dark bluish green ripening to a dull tone; leaves erect, dark bluish green. Brown rust 0, black rust 2. Straw fairly strong.

No. 50. Intermediate in height, somewhat weak; ears dull dark green; leaves erect, somewhat light green. Brown rust 1, black rust 3. Straw very weak.

No. 51. Intermediate in height, somewhat weak; ears somewhat light green; leaves erect, dark green. Brown rust 1, black rust 2. Straw strong.

No. 52. Intermediate in height, weak; ears dull dark green; leaves erect, somewhat dark green. Brown rust 0, black rust 2. Straw strong.

4. Very late.

No. 53. Short; ears somewhat light bright green; leaves erect, very dark green. Brown rust 1, black rust 2. Straw somewhat weak.

No. 54. Intermediate in height; ears dark green; leaves erect, dark bluish green. Brown rust 2, yellow rust 1, black rust 4. Straw weak.

No. 55. Intermediate in height, tillers well; ears light bright green; leaves erect, very dark green. Brown rust 0, black rust 2. Straw strong.

No. 56. Intermediate in height, very weak; ears dull dark green; leaves erect, somewhat light bluish green. Brown rust 1, black rust 3. Straw weak.

No. 57. Tall, strong; ears rather dark green ripening to a dull tone; leaves erect, very dark green. Brown rust 0, black rust slight. Straw strong.

var. *erythroleucon* Kcke.

Ears bearded, glumes smooth red, grain white.

This variety comprises fourteen agricultural types which fall into three groups according to maturity. One culture was rejected on account of want of uniformity arising from natural cross-fertilization. The field observations on which the classification is based were made in 1915.

1. Early.

No. 58. Intermediate in height, weak; ears dark bright green; leaves broad, drooping, dark green with moderate bloom. Brown rust 3, yellow rust 3, black rust 2. Straw very weak.

No. 59. Tall, vigorous; ears bright dark green; leaves erect, dark green (darker than No. 60) with moderate bloom. Brown rust 3, yellow rust 3, black rust 1. Straw fairly strong.

No. 60. Tall, weak; ears light dark green; leaves slightly drooping, broad, dark green with much bloom. Brown rust 3, yellow rust 1, black rust 1. Straw weak.

2. Intermediate in maturity.

No. 61. Tall; ears light green; leaves erect, dark green with much bloom. Brown rust 2, yellow rust 1, black rust 1. Straw fairly strong.

No. 62. Tall; ears light green; leaves erect, dark bluish green with much bloom. Brown rust 3, yellow rust 1, black rust 2. Straw fairly strong.

No. 63. Tall, vigorous; ears very light green; leaves erect, broad, light green with moderate bloom. Brown rust 2, yellow rust 1, black rust 2. Straw fairly strong.

No. 64. Intermediate in height; ears dark green; leaves erect, darh green with much bloom. Brown rust 2, yellow rust 1, black rust 1. Straw weak.

No. 65. Tall (taller than No. 64), weak; ears dark green; leaves erect, dark green (lighter than Nos. 64 and 66) with much bloom. Brown rust 2, yellow rust 1, black rust 1. Straw weak.

No. 66. Intermediate in height, weak; ears dark green; leaves erect, dark green with much bloom. Brown rust 2, yellow rust 2, black rust 2. Straw weak.

Nos. 64, 65 and 66 closely resemble each other in the field. No. 65 is taller and has lighter foliage than No. 64. No. 66 is shorter and more susceptible to yellow and black rusts than the other two.

No. 67. Intermediate in height, vigorous; ears very light green; leaves erect, dark green with slight bloom. Brown rust 1, yellow rust 2, black rust 4. Straw fairly strong.

3. Late.

No. 68. Intermediate in height; ears dark green; leaves erect, dark green with slight bloom. Brown rust 1, yellow rust 1, black rust 2. Straw fairly strong.

No. 69. Intermediate in height; ears dark green (lighter than No. 68); leaves erect, dark green with slight bloom. Brown rust 2, yellow rust 2, black rust 3. Straw fairly strong.

Nos. 68 and 69 are nearly alike in the field and only differ in the colour of the ears and in rust resistance.

No. 70. Intermediate in height, strong; ears somewhat light dull green; leaves somewhat drooping, dark green. Brown rust 1, black rust 2. Straw weak.

No. 71. Tall, weak; ears dark green (darker than No. 69); leaves erect, dark bluish green with much bloom. Brown rust 2, yellow rust 1, black rust 2. Straw weak.

var. *ferrugineum* Al.

Ears bearded, glumes smooth red, grain red.

This variety comprises the following nine agricultural types which separate into four groups according to the time of maturity. The observations on the incidence of rust were made in 1915 when the conditions were favourable for yellow rust.

1. Early.

No. 72. Short; ears dark green; leaves somewhat drooping, dark green with a moderate amount of bloom. Brown rust 4, yellow rust 2, black rust 2. Straw weak.

No. 73. Intermediate in height; ears light dull green; leaves somewhat erect, light dull green. Brown rust 4, yellow rust 2, black rust 2. Straw very weak.

No. 74. Tall, maturing later than Nos. 72 and 73; ears light bright green; leaves erect, light bright green. Brown rust 2, yellow rust 1, black rust 3. Straw weak.

2. Intermediate in time of maturity.

No. 75. Intermediate in height, weak; ears light bright green; leaves erect, light bright green with little bloom. Brown rust 3, yellow rust 1, black rust 3. Straw fairly strong.

No. 75 ripens later and there is less bloom on the leaves than in Nos. 76 and 77.

No. 76. Intermediate in height, vigorous; ears light green; leaves erect, somewhat light green with well developed bloom. Brown rust 2, yellow rust 1, black rust 2. Straw fairly strong.

No. 77. Intermediate in height, vigorous; ears light green (lighter than No. 76); leaves erect, somewhat light green with a moderate amount of bloom. Brown rust 1, yellow rust 1, black rust 2. Straw somewhat weak.

3. Late.

No. 78. Short, weak; ears somewhat light green; leaves erect, dark green with slight bloom. Brown rust 3, yellow rust 3, black rust 3. Straw weak.

No. 79. Intermediate in height, weak; ears dark green; leaves erect, somewhat dark green with slight bloom. Brown rust 3, yellow rust 3, black rust 2. Straw very weak.

4. Very late.

No. 80. Intermediate in height, erect; ears light bluish green; leaves erect, light green with moderate bloom. Brown rust 2, yellow rust 1, black rust 3. Straw weak.

var. *nigricans.*

Ears bearded, glumes smooth, black on a white ground, awns black, grain red.

This new variety comprises twenty agricultural types which fall into four classes according to the time of maturity. Most of the types are characterized by a high degree of rust-resistance while Nos. 87, 89, 94, 95 and 98 are noteworthy in this respect. The observations on which the classification is based were made in 1916.

1. Very early.

No. 81. Short ; ears dull light green ; leaves erect, broad, dark green. Brown rust 0, black rust 1. Straw very weak.

No. 82. Intermediate in height ; ears dull light green ; leaves erect, somewhat light green. Brown rust 0, black rust 1. Straw very weak.

No. 83. Intermediate in height ; ears dark green ; leaves drooping, light green. Brown rust 1, black rust 1. Straw very weak.

2. Early.

No. 84. Tall ; ears dull light green ; leaves erect, light green. Brown rust 0, black rust 1. Straw somewhat weak.

No. 85. Tall ; ears dull dark green ; leaves erect, dark green (darker than No. 86). Brown rust 0, black rust 1. Straw somewhat weak.

No. 86. Intermediate in height ; ears dull dark green ; leaves erect, dark green. Brown rust 0, black rust 1. Straw very weak.

Nos. 85 and 86 are nearly alike in the field and differ only in height, in the set of leaves, in the tone of colour of the ears and in strength of straw.

No. 87. Intermediate in height, fairly strong ; ears dull light green ; leaves erect, somewhat light green. Brown rust very slight, black rust very slight. Straw strong.

No. 88. Intermediate in height, fairly strong ; ears dull dark green, leaves erect, very dark green. Brown rust 0, black rust 1. Straw somewhat weak.

No. 89. Intermediate in height, fairly strong ; ears bright light green ; leaves erect, somewhat light green. Brown rust 0, black rust very slight. Straw fairly strong.

3. Intermediate in time of maturity.

No. 90. Intermediate in height ; ears bright dark green ; leaves erect, dark green. Brown rust 0, black rust 1. Straw somewhat weak.

No. 91. Tall ; ears somewhat bright dark green ; leaves erect, rather light green. Brown rust 0, black rust 1. Straw weak.

No. 92. Tall ; ears dull dark green ; leaves dark green. Brown rust 0, black rust 1. Straw weak.

No. 93. Intermediate in height, fairly strong ; ears dull dark green ; leaves erect, dark green. Brown rust 0, black rust 1. Straw strong.

Nos. 90, 91, 92 and 93 closely resemble one another in the field. No. 91 is the earliest, No. 93 the latest. No. 90 has bright ears, No. 91 somewhat bright ears while the other two have ears of a dull tone.

4. Very late.

No. 94. Intermediate in height, strong; ears dull dark green; leaves erect, very dark green. Brown rust 0, black rust very slight. Straw strong.

No. 95. Intermediate in height, strong, earlier than No. 94; ears dark green (brighter than No. 94). Brown rust 0, black rust very slight. Straw strong.

No. 96. Intermediate in height, strong; ears somewhat bright dark green; leaves erect, somewhat light green. Brown rust 0, black rust 1. Straw fairly strong.

No. 97. Tall, weak; ears dull dark green; leaves erect, somewhat light green. Brown rust very slight, black rust 2. Straw weak.

No. 98. Intermediate in height (shorter and earlier than No. 94), strong; ears dull dark green; leaves erect, dark green. Brown rust 0, black rust very slight. Straw fairly strong.

No. 99. Tall; ears dull dark green; leaves erect, dark green. Brown rust 0, black rust 1. Straw fairly strong.

No. 100. Tall, fairly strong, very late; ears dull dark green; leaves erect, dark green. Brown rust 0, black rust 1. Straw strong.

var. *indicum*.

Ears bearded, glumes smooth black on a red ground, awns black, grain white.

This new variety comprises nine agricultural types which fall into three groups according to time of maturity. All (particularly No. 109) exhibit a considerable degree of resistance to rust. The observations on which the classification was drawn up were made in 1916.

1. Very early.

No. 101. Short, strong; ears dull light green; leaves erect, light green. Brown rust 0, black rust 1. Straw somewhat weak.

No. 102. Short, strong; ears light green; leaves erect, dark green. Brown rust 1, black rust 1. Straw strong.

2. Early.

No. 103. Intermediate in height, strong; ears dull dark green; leaves erect, dark green. Brown rust 1, black rust 1. Straw somewhat weak.

No. 104. Intermediate in height, strong; ears somewhat light green; leaves erect, somewhat light green. Brown rust 1, black rust 1. Straw weak.

No. 105. Short, weak; ears very light dull green; leaves erect, dark green. Brown rust 1, black rust 2. Straw weak.

No. 106. Short, strong; ears very light green (brighter than No. 105); leaves erect, dark green. Brown rust 0, black rust 2. Straw weak.

3. Late.

No. 107. Intermediate in height, strong; ears light bright green; leaves erect, somewhat light green. Brown rust 1, black rust 2. Straw strong. The earliest type of the late group.

No. 108. Intermediate in height, strong; ears light green ripening to a dull tone; leaves erect, dark green. Brown rust 0, black rust 1. Straw strong.

No. 109. Intermediate in height, strong; ears light bright green; leaves erect, light green. Brown rust 0, black rust very slight. Straw strong.

var. *bengalensis*.

Ears bearded, glumes smooth, black on a red ground, awns black, grain red.

This new variety consists of twelve agricultural types which fall into three classes according to the time of maturity. The observations on which the classification was drawn up were made in 1915.

1. Very early.

No. 110. Short, vigorous; ears light green with moderate bloom; leaves erect, light green. Brown rust 1, yellow rust 1, black rust 2. Straw fairly strong.

2. Early.

No. 111. Intermediate in height, weak; ears dark green with moderate bloom; leaves broad, somewhat drooping, dark green. Brown rust 2, yellow rust 1. Straw fairly strong.

No. 112. Intermediate in height, vigorous; ears light bluish green with moderate bloom; leaves somewhat drooping, light green. Brown rust 1, yellow rust 1, black rust 1. Straw weak.

No. 113. Intermediate in height; ears somewhat light green (darker than Nos. 112 and 114) with much bloom; leaves somewhat drooping, light green. Brown rust 1, yellow rust 1, black rust 1. Straw weak.

No. 114. Tall, vigorous; ears erect, light green with moderate bloom. Brown rust 1, yellow rust 1, black rust 1. Straw fairly strong.

Nos. 112 and 114 are nearly alike in the field and only differ in height, in the set of the leaves and in standing power.

3. Late.

No. 115. Intermediate in height, vigorous; ears rather dark green with much bloom; leaves erect, dark green. Brown rust 2, yellow rust 1, black rust 1. Straw weak.

No. 116. Intermediate in height, vigorous; ears rather dark green with much bloom; leaves slightly drooping, dark green. Brown rust 3, yellow rust 1, black rust 1. Straw weak.

Nos. 115 and 116 closely resemble each other in the field and only differ in resistance to brown rust and in the set of the leaves.

No. 117. Tall; ears somewhat dark green (lighter than Nos. 118 and 119) with much bloom; leaves slightly drooping, dark green (lighter than Nos. 118 and 119). Brown rust 2, yellow rust 1, black rust 2. Straw weak.

No. 118. Tall, rather weak; ears somewhat dark green with much bloom (more than No. 119); leaves erect, broad (broader than No. 119), dark green. Brown rust 2, yellow rust 1, black rust 1. Straw weak.

No. 119. Tall, weak; ears rather dark green with moderate bloom; leaves erect, dark green. Brown rust 3, yellow rust 1, black rust 2. Straw weak.

No. 120. Intermediate in height, weak; ears rather dark green with much bloom; leaves slightly drooping, dark green. Brown rust 1, yellow rust 1, black rust 1. Straw weak. (No. 120 is earlier than No. 121.)

No. 121. Intermediate in height, weak; ears rather dark green with very much bloom; leaves erect, dark green. Brown rust 1, yellow rust 1, black rust 1. Straw very weak.

var. *meridonale* Kcke.

Ears bearded, glumes felted white, grain white.

This variety is represented by a single agricultural type which is exceedingly susceptible to black rust.

No. 122. Early, intermediate in height, strong; ears dull dark green; leaves erect, very dark green. Brown rust 1, black rust 4. Straw weak.

PREFACE

THE following account of the operations against bud-rot of palms in South India is written because the application of the Pest Act marks the end of a phase of the operations and the continuance of the work from July 1920 passed to the hands of M. R. Ry. S. Sundararaman Avargal, my successor as Government Mycologist in the Madras Department of Agriculture. I have pleasure in acknowledging great assistance from him in the work during the eleven years he was my chief assistant.

W. McRAE.

CONTENTS

I. HISTORY OF THE OPERATIONS AGAINST BUD-ROT OF PALMS IN SOUTH INDIA.

BY

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Account of the operations in Godavari and Kistna Districts.

In 1904 the outbreak of a serious disease of the palmyra palm, *Borassus flabellifer* Linn., in the Godavari delta on the east coast of the Madras Presidency was reported and Dr. Butler, the Imperial Mycologist, paid a visit to the delta in August 1905. The result of his investigation determining the cause to be *Phytophthora palmivora* Butl., the measures he recommended and the early history of the operations undertaken against the disease are given in his paper entitled the "Bud-rot of palms in India."[1] For the details of the operations to the end of 1909 his paper should be consulted, but I shall give a résumé of what was done up to that time in order to make clear the further account of the operations which this paper presents. Briefly the recommendations were (1) the formation of a special staff of agricultural inspectors or some similar officials under whom would work groups of expert palm-climbers, (2) that some of the latter should cut off the green tops below the swelling of the leaf-sheaths from all diseased trees both those in the early stages and those already dead, (3) that after cutting off the heads the whole of the tops should be collected into a heap in each village and burned, and (4) that other palm-climbers should brush Bordeaux mixture on the leaf-sheaths of healthy trees in places where the latter were surrounded by large numbers of dead and dying trees, in order to diminish the chances of infection.

In December 1906 trial measures were instituted by the Agricultural Department of Madras in three *firkas* or sub-divisions of Cocanada,

[1] Butler, E. J. *Mem. Dep. Agri. India, Bot. Ser.*, Vol. III, pp. 221-280, 1910. Fungi and Disease in Plants, p. 95, 1918.

Ramachandrapur and Amalapur Taluqs, and by March 1907 about 40,000 diseased trees had been dealt with. This was in reality but an experiment to gain experience and to see whether the measures were practicable, for there was some doubt and hesitation at first in undertaking remedial measures on the large scale that was obviously required. The main difficulties that were encountered in carrying out the work are given in pages 266 to 270 of Dr. Butler's memoir. Some of them have remained throughout the operations, while others have been to a great extent overcome.

In June 1907 operations on a large scale with eight revenue inspectors were begun in Amalapur Taluq, but still only a fraction of the infected area was tackled. The general control was entrusted to an Assistant Collector while three mycological assistants and an agricultural demonstrator were appointed as supervisors. "By December 1907 the whole of the infected area of Amalapur Taluq had been worked over and all the old cases cut out. The first return visit had been paid in most villages and the second was in progress. This set free a portion of the staff and the work was accordingly extended to Ramachandrapur Taluq by the beginning of 1908. A considerable recrudescence in Amalapur Taluq in January and February 1908 detained about half the staff south of the Gautami until the hot weather. By the 1st April 1908 the returns showed that 177,000 palms had been cut in Amalapur Taluq since the beginning of the operations and probably over a quarter of a million in the whole area."[1] In October 1908 the Assistant Collector was transferred and as his successor, a Special Deputy Collector, did not join till July, the work suffered through want of supervision. Before this two of the supervisors had been withdrawn and soon afterwards the other two left. Up to October 1908 actual cutting was done by hired tappers (palm-climbers) working under the direction of revenue inspectors who moved with their parties from village to village. Each revenue inspector had to visit every village in his range, engage the necessary tappers for cutting and coolies for burning and personally supervise the operations in the field. The number of villages in each range being large, the interval between one visit and the next was too great. So long as it was believed that the disease progressed rapidly and continuously from the time of infection to the death of the tree and that a new outbreak could not occur in cleared-up areas without infection from outside the arrangement seemed satisfactory, but the repeated recrudescences in Amalapur Taluq suggested that the interval between infection and death was much longer than was anticipated. Besides, up to this time, only

[1] Butler, E. J. *Mem. Dep. Agri. India, Bot. Ser.*, Vol. III, p. 270, 1910. Fungi and Disease in Plants, p. 95, 1918.

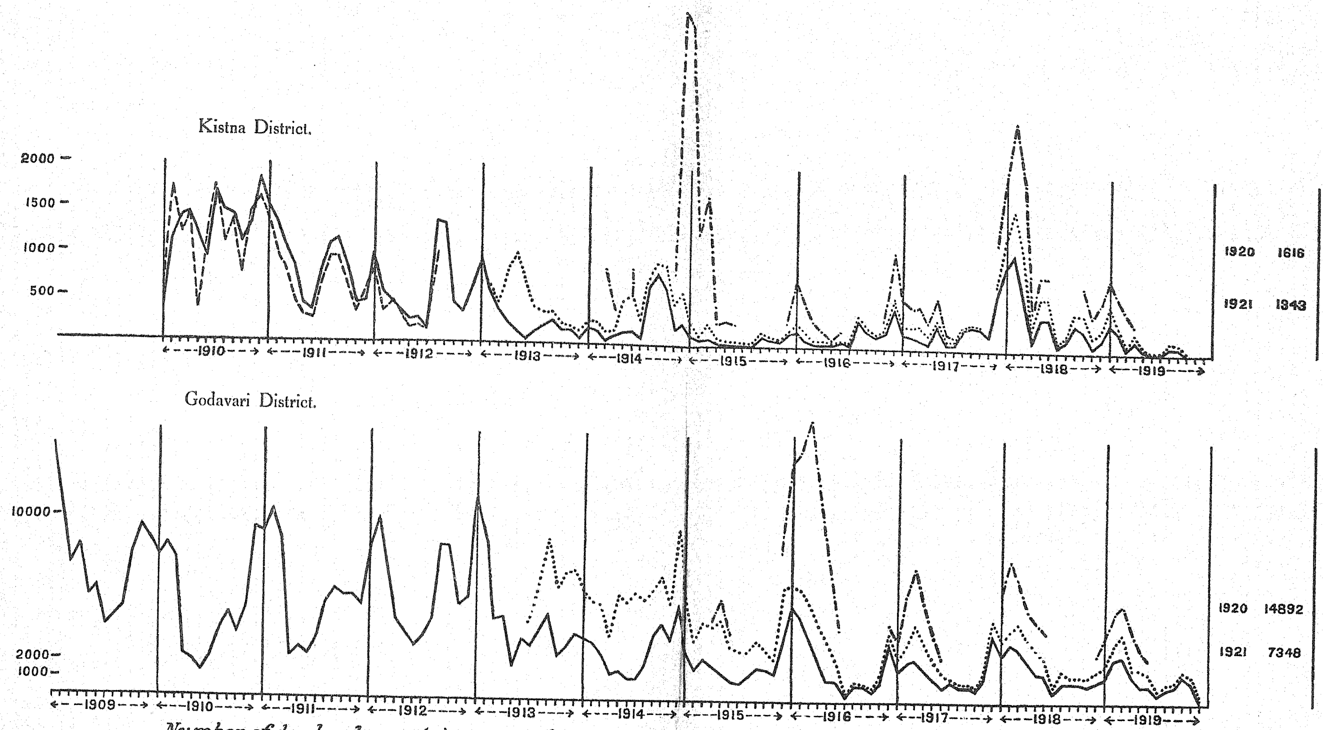
a portion of the infected area in the Godavari District had been worked over, while the Kistna District was untouched. This way of carrying out measures against the disease was thus obviously ineffective both with regard to the area covered and to the whole infected area.

From October 1908 accordingly Mr. Green, the Special Deputy Collector, introduced a new system of carrying out the operations under which actual cutting and burning was to be carried out by the tappers and village servants under the direction of the village officers upon whom was thrown the responsibility for getting the work done. The members of the special staff were relieved of the actual cutting and burning of dead palms and became inspecting officers. This was the aim of the new system but only gradually did it take effect in practice and not till 1920, when the Pest Act was applied, was it fully realized. A great improvement also was the fact that for the first time the whole of the known infected area in the Godavari District was brought under the operations at the end of 1908 and that of the Kistna District in 1910.

While the village officer was moving about in the village on revenue duty he noted the position of dead trees and arranged to have them cut. When large numbers of dead palms were found in small areas it was easy, but it was difficult to get a tapper to cut isolated palms or groups of palms scattered throughout a village whose area might be ten square miles, because he had to spend a considerable amount of time and energy going about the village for a small return. At first the trunks of the cut trees were tar-marked and afterwards they were numbered with different coloured paints to distinguish those of different years. Though tedious, this was necessary in the beginning till the village officers and revenue inspectors became accustomed to the work. Because of the obliteration of the numbers by weathering and the consequent loss of the field record, registers were maintained from 1914 showing the survey number of every field in which disease was found, and month by month the numbers of dead palms cut were marked in the appropriate places. The revenue inspectors took the registers out with them and checked the number of headless stems in each field, noted any recently dead palms they saw and paid for the cost of cutting the trees which at different times varied from $\frac{1}{4}$ to $1\frac{1}{2}$ annas per tree. The village officers and the revenue inspectors reported the number cut and the number paid for respectively, the idea being that the one set of figures would be a check on the other. During 1909 and 1910, however, there was always a discrepancy between the monthly numbers reported and a very great difference between the sums of the two sets of figures for the year. In the graph for Kistna District is given as a dotted

line the figures reported by the village officers for 1910, 1911 and 1912, and as a continuous line those reported by the revenue inspectors as paid for during those years. As was to be expected in the first year the two curves differ widely, but in 1910 and 1911 they approximate closely. After a thorough investigation the reports of the village officers were discontinued as being unreliable and in the circumstances impracticable to make accurate. The village officers had a great deal of other regular work to do especially in the double crop lands where the disease was worst, besides the operations were very unpopular with the cultivators. The village officers accordingly had much reason for, and many opportunities of, relegating the operations to a secondary place or even doing little or nothing especially where a revenue inspector was none too eager to walk about the fields in the hot sun inspecting what had been done. Too often the work was left till the arrival of the revenue inspectors in the village when a spurt was made to get the dead trees cut. However, too much must not be made of this. The difficulties of introducing an entirely new and little understood system of dealing with a disease were very real and entailed patient, continuous effort to overcome. Gradually as the years passed the work was better done and the tree owners were even induced to bear the cost of the tappers' wages, thus showing that they did ultimately have some belief in the operations, and from 1915 onwards the cost of the special staff was practically all that fell to be charged to Government funds. The years from 1909 in the Godavari District and 1910 in the Kistna District till 1912 were spent in getting the operations as efficient as possible. During this time there was a gradual slight increase in the number of dead palms dealt with, and facts were gradually accumulating that led to more intensive measures for dealing with the disease in the field, but these will be discussed later.

The record of the numbers of diseased palms dealt with during the fifteen years the operations have been in existence is given in Tables I—III and graphically in Plate I where graphs are given for Kistna and Godavari Districts. These two blocks were kept separate with a view to seeing more clearly what was going on in the infected area, for in several ways they had separate characteristics. For the sake of convenience in recording the figures the diseased palms were divided into three categories corresponding somewhat to the symptoms of the disease, *viz.*, (1) *dead palms* in which the central leaf or group of leaves was dead indicating that the growing point was dead, (2) "*outwardly infected*" *palms* in which one or more of the leaves had characteristic rows of spots indicating that the growing point was still alive and (3) "*inwardly infected*" *palms* in which the presence of the disease was



——— Number of dead palms cut in a month.
.... " dead + outwardly infected palms.
-.-.-.- " dead + " " " inwardly infected palms.
– – – " dead palms reported by village officers.

TABLE I.

Yearly figures of cuttings.

Year	Godavari District				Kistna District				Total			
	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total
1907 ..	..	..	215,229	215,229	..	..	..	..	..	..	215,229	215,229
1908 ..	..	..	183,100	183,100	..	..	..	..	..	..	183,100	183,100
1909 ..	..	..	91,849	91,849	..	..	..	..	..	..	91,849	91,849
1910 ..	..	..	58,765	58,765	..	..	15,561	15,561	..	..	74,326	74,326
1911 ..	..	..	67,921	67,921	..	..	10,466	10,466	..	..	78,387	78,387
1912 ..	..	..	72,345	72,345	..	..	7,107	7,107	..	..	79,452	79,452
1913 ..	..	19,088	55,204	74,292	..	3,122	3,265	6,387	..	22,210	58,469	80,679
1914 ..	570	38,765	32,842	72,177	4,792	2,347	3,515	10,654	5,362	41,112	36,357	82,831
1915 ..	5,733	23,379	21,847	50,959	6,629	673	721	8,023	12,362	24,052	22,568	58,982
1916 ..	41,337	11,791	25,133	78,261	1,830	711	1,696	4,237	43,167	12,502	26,829	82,498
1917 ..	12,286	8,370	19,873	40,529	1,662	882	2,497	5,041	13,948	9,252	22,370	45,570
1918 ..	12,837	11,529	20,987	45,353	4,080	2,616	4,488	11,184	16,917	14,145	25,475	56,537
1919 ..	7,517	7,717	15,860	31,094	665	703	975	2,343	8,182	8,420	16,835	33,437
1920 ..	..	..	14,892	14,892	..	..	1,616	1,616	..	..	16,508	16,508
1921 ..	..	..	7,349	7,349	..	..	1,343	1,343	..	..	8,692	8,692
TOTAL ..	80,280	120,639	903,196	1,104,115	19,658	11,054	53,250	83,962	99,938	131,693	956,446	1,188,077

TABLE II.

Monthly figures of cuttings in Godavari District.

Month	1909	1910	1911	1912	1913			1914				1915			
	Dead	Dead	Dead	Dead	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total
Jan. ..	14,090	7,731	9,194	8,348	..	11,139	11,139	..	2,519	3,416	5,935	..	2,801	2,614	5,415
Feb. ..	10,532	8,688	10,590	10,172	..	8,965	8,965	..	2,219	3,182	5,401	..	1,630	1,664	3,294
March ..	7,284	7,745	8,948	7,301	..	4,365	4,365	..	2,864	2,503	5,367	..	2,123	2,291	4,414
April ..	8,534	2,280	2,140	4,306	..	4,892	4,892	..	2,321	1,375	3,696	221	2,218	1,930	4,369
May ..	5,636	2,014	2,853	3,623	..	1,838	1,838	..	4,378	1,555	5,933	1,125	3,096	1,398	5,619
June ..	6,153	1,401	2,389	2,882	..	3,325	3,325	570	4,313	1,111	5,994	713	1,966	1,061	3,740
July ..	3,826	2,186	3,439	3,353	1,453	2,972	4,425	..	4,819	1,226	6,045	..	1,832	964	2,796
Aug. ..	4,487	3,865	5,367	4,322	1,853	3,890	5,743	..	3,738	1,923	5,661	..	1,333	1,395	2,728
Sept. ..	4,940	4,800	6,254	8,619	4,232	4,755	8,987	..	2,604	3,598	6,202	..	1,391	1,946	3,337
Oct. ..	8,054	3,583	5,754	8,634	3,844	2,434	6,278	..	2,650	4,308	6,958	..	1,067	1,789	2,856
Nov. ..	9,561	4,860	5,793	5,096	4,121	2,967	7,088	..	2,228	3,197	5,425	245	785	1,486	2,516
Dec. ..	8,752	9,612	5,200	5,689	3,585	3,662	7,247	..	4,112	5,448	9,560	3,429	3,137	3,309	9,875
TOTAL ..	91,849	58,765	67,921	72,345	19,088	55,204	74,292	570	38,765	32,842	72,177	5,733	23,379	21,847	50,959

TABLE II—*contd.*

Monthly figures of cuttings in Godavari District.

Month	1916				1917				1918				1919			
	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total
Jan. ..	6,739	1,190	5,408	13,337	1,132	647	1,663	3,442	2,679	921	2,610	6,210	1,265	794	1,475	3,534
Feb. ..	7,749	1,646	4 707	14,102	2,928	939	2,283	6,150	3,097	1,710	3,445	8,252	1,580	1,002	2,454	5,036
March	10,446	2,181	3,331	15,958	3,331	1,471	2,950	7,752	2,353	1,445	3,126	6,924	1,663	1,352	2,634	5,649
April ..	7,558	2,039	2,334	11,931	2,195	1,568	1,894	5,657	1,427	1,341	2,453	5,221	1,342	1,218	1,705	4,265
May ..	5,117	2,196	1,175	8,488	1,186	1,160	1,405	3,751	1,482	1,478	1,716	4 676	1,077	1,030	1,011	3,118
June ..	3,108	1,226	1,060	5,394	839	858	775	2,472	1.077	1,260	1,552	3,889	590	757	1,055	2,402
July ..	33	67	233	333	99	266	1,062	1,427	5	460	511	976	..	238	538	776
Aug. ..	39	262	871	1,172	10	222	966	1,198	..	762	1,107	1,869	..	371	987	1,358
Sept. ..	..	195	830	1,025	..	184	879	1,063	..	508	1,091	1,599	..	316	1,060	1,376
Oct. ..	..	135	565	700	6	149	705	860	..	508	1,095	1,603	..	295	1,540	1,835
Nov. ..	45	257	1,251	1,553	62	171	1,313	1,546	..	505	1,029	1,534	..	327	1,293	1,620
Dec. ..	503	397	3,368	4,268	498	735	3,978	5,211	717	631	1,252	2,600	..	17	108	125
TOTAL	41,337	11,791	25,133	78,261	12,286	8,370	19,873	51,029	12,837	11,529	20,987	45,353	7,517	7,717	15,860	31,094

Table III.

Monthly figures of cuttings in Kistna District.

Month	1910	1911	1912	1913			1914				1915				1916			
	Dead	Dead	Dead	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total
Jan. ..	367	1,546	1,010	..	978	978	..	89	202	291	3,345	172	104	3,621	501	92	194	787
Feb. ..	1,169	1,356	581	66	590	656	..	68	173	241	1,116	57	68	1,241	365	110	75	550
March ..	1,419	1,075	417	102	348	450	713	67	69	849	1,456	160	87	1,703	162	66	25	253
April ..	1,490	882	352	633	213	846	250	57	105	412	158	72	36	266	59	55	35	149
May ..	1,264	411	264	949	131	1,080	21	341	152	514	217	49	18	284	45	17	18	80
June ..	937	346	296	646	25	671	281	417	153	851	210	31	17	258	58	71	67	196
July ..	1,726	817	159	302	112	414	..	219	72	291	..	9	14	23	..	9	24	33
Aug. ..	1,497	1,103	1,368	150	199	349	..	89	688	777	..	1	14	15	..	49	318	367
Sept. ..	1,476	1,190	1,325	103	262	365	..	103	810	913	..	50	110	160	..	48	184	232
Oct. ..	1,103	837	415	55	174	229	..	218	650	898	..	16	81	97	..	40	112	152
Nov. ..	1,279	428	317	62	141	203	328	284	192	804	..	21	45	66	117	29	178	324
Dec. ..	1,834	475	603	54	92	146	3,199	365	249	3,813	127	35	127	289	523	125	466	1,114
Total ..	15,561	10,466	7,107	3,122	3,265	6,387	4,792	2,347	3,515	10,654	6,629	673	721	8,023	1,830	711	1,696	4,237

TABLE III—*contd.*

Monthly figures of cuttings in Kistna District.

Month	1917				1918				1919				1920	1921
	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total	Inwardly infected	Outwardly infected	Dead	Total		
Jan.	334	73	182	589	720	348	904	1,972	281	223	315	819	..	..
Feb.	238	83	168	489	1,007	517	1,100	2,624	208	176	250	634	..	..
March ..	226	133	134	493	805	450	653	1,908	66	19	32	117	..	..
April	126	86	80	292	191	159	91	441	91	106	118	315	..	..
May	175	151	280	606	465	482	782	1,729	18	34	34	86	..	..
June	93	59	43	195	..	..	..	..	1	5	4	10	..	..
July	..	52	61	113	..	53	59	112	..	8	7	15	..	..
Aug.	..	25	226	251	..	75	115	190	..	70	92	162	..	..
Sept.	..	37	283	320	..	115	345	460	..	48	90	138	..	..
Oct.	..	33	250	283	326	170	265	761	..	14	33	47	..	..
Nov.	56	23	161	240	225	134	46	405	..	..	..	..	..	..
Dec.	414	127	629	1,170	341	113	128	582	..	..	..	..	..	..
TOTAL ..	1,662	882	2,497	5,041	4,080	2,616	4,488	11,184	665	703	975	2,343	1,616	1,343

detected by stripping the leaf-bases from palms that showed no outward symptoms of disease but that grew in the vicinity of dead or outwardly infected palms. These terms have no significance other than that given in the definitions. They were evolved in talking with the special staff about the work in the field and crept into use in administrative reports as being a convenient way to indicate the appearance of diseased palms as dealt with in the stages of the operations. The numbers of the trees dealt with were reported in this way in order that we might be the better informed as to the progress of the operations. The outwardly infected and inwardly infected trees had all the diseased tissue excised and thus were given a chance of recovery.

With regard to the value of the figures, those of the first category have a reasonable degree of accuracy as it is easy enough to distinguish a dead tree, while those of the other two are not quite so accurate being most probably a little too high especially in the second category. The village officers at first did not always distinguish between rows of spots caused by the fungus and rows of holes caused by the rhinoceros beetle. Again the death of the central leaf or even the two next to it does not absolutely mean that the central growing-point is dead, though as a matter of fact it generally does so from the point of view of the ordinary operations. If the crown is dissected immediately the leaves show the yellow discoloration, the growing-point in a great many cases is found not to be dead and the tree can be saved. But a few days later the tissue about the growing-point becomes involved in the rot and it is too late to save the tree. During the "detailed examination" of trees mentioned on page 36 and succeeding pages such cases would be dealt with in increasing numbers and they would naturally be included among the outwardly infected palms for the lack of another division into which to put them. The trees were diseased and were saved as the outwardly infected ones were. The only material error in the second category, I think, crept in during 1914 when outwardly infected palms were first being dealt with on a large scale in the Godavari District. On page 4 of a note on the "Rows of Spots on Palmyra Palms" published in the *Agricultural Journal of India*, VII, 1912, I gave three examples in which the percentage of outwardly infected palms was 17, 8 and 3·4 respectively, and mentioned that I thought the percentage of such trees over the whole area was slightly below the last figure. The numbers of the outwardly infected and dead palms in Godavari District from July 1913 when the former began to be cut till December 1914 are as follows :—

Month				Outwardly infected	Dead			
July	1913	..	..	1,453	2,972 or	1 : 2	or	33 per cent.
Aug.	,,	..	..	1,853	3,890	1 : 2		32 ,,
Sept.	,,	..	..	4,232	4,755	1 : 1		47 ,,
Oct.	,,	..	..	3,844	2,434	8 : 5		61 ,,
Nov.	,,	..	..	4,121	2,967	8 : 6		58 ,,
Dec.	,,	..	..	3,585	3,662	1 : 1		49 ,,
Jan.	1914	..	..	2,519	3,416	5 : 7		42 ,,
Feb.	,,	..	..	2,219	3,182	2 : 3		41 ,,
Mar.	,,	..	..	2,864	2,503	1 : 1		53 ,,
Apr.	,,	..	..	2,321	1,375	11 : 7		62 ,,
May	,,	..	..	4,378	1,555	3 : 1		73 ,,
June	,,	..	..	4,313	1,111	4 : 1		71 ,,
July	,,	..	..	4,819	1,226	4 : 1		79 ,,
Aug.	,,	..	..	3,738	1,923	2 : 1		66 ,,
Sep.	,,	..	..	2,604	3,598	2 : 3		42 ,,
Oct.	,,	..	..	2,650	4 308	5 : 8		38 ,,
Nov.	,,	..	..	2,228	3,197	2 : 3		41 ,,
Dec.	,,	..	..	4,112	5,448	4 : 5		43 ,,

Even taking into account the reservation made in the early part of this paragraph the number of outwardly infected trees is too high in all these months. Anything like these numbers of outwardly infected palms would have been strikingly conspicuous, but the appearance in the delta was not so. I am willing to admit that my first estimate was far too low but not to the extent that these figures indicate. Again through an unfortunate misunderstanding the person then in charge of the operations thought the relative proportion of outwardly infected to dead palms should not be less than 2 : 1, and in April 1914 issued instructions accordingly to all revenue inspectors and threatened penalties if the reports showed otherwise. It was only after I had had several monthly reports and noticed the unexpectedly high proportion that I found this out, had the instructions cancelled and took pains to have the inspectors carefully instructed. The figures for the inwardly infected palms are fairly accurate. The only likely error would be the inclusion of trees that had brown blotches on the leaf-sheaths especially near the edges, but as these are not at all like the spots caused by the fungus this error would be insignificant after the first detailed examination of trees. I have no means of accurately estimating the errors which on the whole are small and not, I think, any greater than in field work of the class, so I shall use the figures in the discussion as they stand.

I shall now describe the working of the operations from year to year from 1910 onwards mentioning the salient features of the work as they crop up. In 1910 there were 566 villages within the infected area in Godavari District and cuttings were made in 208, while in Kistna District out of 710 villages cuttings were made in 35 in January and 103 in December. The

total number of dead trees cut this year in the whole infected area was considerably less than the number cut in the previous year in Godavari District alone, and this gave considerable encouragement with regard to the continuance of the operations. In 1911 on the transference of the Special Deputy Collector he was replaced by two Tahsildars, one for each district, as the two districts were found to be too large for a single officer to supervise properly, and the staff in Godavari District was increased. By 1912 the spread of the disease was definitely checked in both districts. In Kistna District the number of dead palms cut was high in parts of the taluqs of Kovur, Tanuku and Narsapur, but beyond that area there were so few cuttings that the rest of these taluqs and the whole of Bunder and Bhimavaram Taluqs were handed over to the ordinary revenue staff which became responsible for cutting sporadic cases that might occur and for reporting any serious outbreak to the Special Tahsildar. In Godavari District two new infected places at Pittapur and Jagapetinagaram were found in the uplands eight and twelve miles from Samalkota which is at the edge of the delta. In one case the infected area was about forty and in the other about ten acres, the former being situated on one side and the other on both sides of a main road and each being beside a small tank. Both were miles away from the nearest known infected area and from their position it looks as if the disease has been transported there by human agency. In the latter of them 203 dead trees were cut. 584 trees surrounding them were examined by cutting off 17 or 18 of the lower leaf-sheaths and 99 of them were found to be diseased. All had the diseased tissue completely excised and all recovered. From this place the disease was later completely eradicated (no deaths having occurred during the last five years), but occasional deaths still occur in the other. The Collector placed one revenue inspector on duty solely in the uplands so that a better watch could be kept over a belt of five miles on the edge of the infected area in Godavari District. In the years 1911 and 1912 the number of dead trees was slightly above that of 1910 and in the latter year was recorded the highest number of deaths since 1909, but after this date the number gradually and continuously declined. During this period was conducted a set of inoculation experiments which are described separately at the end of this paper.

About this time a proposal was made to abandon the attempt to control the disease within the infected area and to substitute a plan of patrolling a belt round the boundaries of that area. Fortunately, however, the proposal was dropped for obvious reasons; the chief of which being that the number of diseased trees in the infected area was too small a percentage of the total to justify the sacrifice of all, that the patrol of the belt would have had to

continue till most of the trees in the infected area had taken the disease and died, and thus, because of the slow rate of development and spread of the fungus, there would be no determinable limit to the operations, and that there was no certainty that a carefully patrolled belt of reasonable dimensions would stop the spread of the disease beyond it as it was still possible for the disease to be transported long distances by human agency. Effort was accordingly directed to improving the system already in practice.

In 1913 the number of dead trees cut over the whole area fell considerably. Up to this time, however, only dead palms were being destroyed, but a fairly large number of diseased palms showed the presence of disease in the appearance of rows of spots on the laminæ of the leaves.[1] It was found that, when such a leaf protruded from the bud and began to open, the mycelium developed on the surfaces of the spots and produced sporangia in favourable circumstances such as when there was dew in the cold season or a highly moisture-charged atmosphere during the monsoon. In the presence of water, the sporangia discharged zoospores freely and their position on the topmost leaf of the palm was an excellent one for dissemination by dripping on the supporting palm or to lower ones or by rain splashing the zoospore-charged drops of water on the leaf to surrounding palms. Older leaves, however, though they retain traces of mycelium on the old spots, did not appear to have it in an active condition and probably they played a very small part in the dissemination of the fungus. The facts of dissemination could not be actually proved as most of the palms were from 20 to 40 feet high and, so far as I was concerned, unclimbable, but the possibility and the likelihood are not in doubt. The facts of mycelium and spore development were demonstrated by having many of these leaves cut down by tappers and examined. These trees produced a varying number of spotted leaves, the largest number that has been counted on one palm being fifteen in the village of Achanta. As the palm produces roughly a leaf a month[2] these leaves would have offered one after another possibilities for the spread of infection for considerable periods. For example, a palm about 30 feet high was marked in the village of Annampalli in Godavari District in August 1908 as having the laminæ of more than one leaf spotted and it remained alive putting out spotted leaves till January 1912 when the central leaves were noticed to be dead and the crown was cut and burned by a revenue inspector in my absence. I saw it twice in the interval and verified the presence of fungus in ten leaf-sheaths but unfortunately the

[1] McRae, W. Rows of Spots on the Leaves of Palmyra Palms. *Agri. Jour., India,* Vol. VII, pp. 272 to 279.

[2] McRae, W. Growth of the Palmyra Palm. *Indian Forester*, Vol. XLIV, pp. 25, 26, 1918.

number of spotted leaves was not counted at the end. This palm was thus known to have had the disease for three and a half years in a condition favourable for dissemination. Though the people acquiesced in allowing dead palms to be cut, they were extremely averse to having those with spotted leaves cut too. At first I wanted them to be cut and burned as dead trees were, but evidence was gradually accumulating to show that it was unnecessary to destroy them and that they could be saved.

My attention was first attracted to the possibility of a palmyra's recovery by seeing some palms that had recovered after they had been beheaded in the course of the ordinary operations. These new crowns were small and sometimes stuck out at an angle and did not often survive, but one in Itampudi grew well and was under observation for six years. It was cut in 1910 or 1911 and grew till 1917 when it succumbed to the disease, being situated in a most intensely infected part of the village. The trunk was constricted to half its diameter and then widened out to about the same diameter as below the constriction and elongated farther to about four feet. I thought that perhaps a new growing-point might have been formed from the slightly differentiated tissue round the growing-point or in the axil of a young leaf, but on carefully dissecting thirteen young cases I came to the conclusion that it was the original growing-point that had continued growth and produced a new crown. This was possible when the growing-point was not yet dead at the time of operation and the crown was lopped with an axe. As the crown fell over in a piece the uncut tissue was torn asunder and part of it was left covering and protecting the growing-point. In the delta I have seen two cases of branched palmyras, one with up to 30 branches, and two others in the other parts of South India, so there was no reason against a new growing-point being formed, but of this I could get no evidence in the cases examined. However, these cases did show that even after drastic treatment the palmyra had the power to recover, and this led me to consider the possibility of applying the same treatment to the outwardly infected palms to see in what number they would recover.

It was found in examining more than a hundred such palms, that when the fungus was penetrating the bud, which is from one to two feet in length, about the level of the growing-point, the base of the expanding leaf was penetrated and its tissue destroyed, resulting in the leaf withering and presenting the usual symptoms of disease, and as the fungus was in the vicinity of the growing-point the latter's death occurred within a short time. But when the fungus was penetrating the bud at a higher level, the folded laminæ of a young leaf was penetrated, and as it was developing actively it soon pushed

out into the air and expanded, presenting the symptom of disease consisting of a row of characteristic spots on the expanded leaf-blade and seeing the fungus was at a sufficient distance from the growing-point all the diseased tissue of the leaf-bases, petioles and laminæ could be cut off, leaving a mass of truncated leaves around the living growing-point. It was found by trial in several villages in different parts of the infected area, both in the delta and the uplands, that in any season, if this mass of tissue was four inches broad and six inches high the growing-point would not die but would in ninety-four per cent. of cases produce a new crown of leaves which in two years or more would be as large as the original crown. As soon as it became apparent that this kind of thing could be done, I tried the experiment on every occasion I could persuade the owner to allow me to operate on a case and as these trees began to multiply throughout the area, people began to see that there was some real tangible benefit in such an operation. So it became possible to have these trees treated and from February 1913 in Kistna District and July of the same year in Godavari District they were definitely included in the scope of the operations. In Kistna District where each revenue inspector's charge was smaller and lighter than in Godavari District the number of those outwardly infected palms dealt with in the first few months was large and ever afterwards comparatively small. In the latter district, however, the number was high and remained high for several months, thereafter coming down but always remaining substantial.

Simultaneously experiments were being made, whenever possible, in examining apparently healthy palms in the vicinity of dead and outwardly infected ones by cutting off leaf-bases, and it soon became apparent that a very considerable number that showed no outward symptoms were diseased. A few examples will suffice. In September 1910 at Vijheswaram, where dead trees had persistently appeared during the year, twenty-one were examined that all looked quite healthy : indeed the tapper said it was useless to climb them looking for disease. Ten had the disease, seven having living fungus and three dead fungus. The seven had 8, 9, 15, 22, 24, 25 and 29 leaf-bases spotted respectively and the three had 2, 3 and 7 respectively. About the same time at Rajabhupalàpatnam forty apparently healthy palms were examined similarly in a field in which diseased trees were being cut, and fourteen of them had the disease. At Jagapatinagaram 203 dead trees were cut after the disease was discovered there in 1912. In October 584 healthy looking palms in the immediate vicinity were examined and 99 of them were diseased. At Siddhantham, in a part where trees were not climbed so much as usual, those round two dead and two outwardly infected palms were

examined and altogether thirty-four inwardly infected tall trees were discovered. These palms were not being touched by the operations till after a longer or shorter period of months they showed the outward symptoms. The record of the last mentioned example shows where infection begins. Disease spots were found in twenty-six trees to begin on the tenth or a lower leaf-sheath, counting upwards from the lowest leaf-sheath on the tree, in six to begin from the eleventh to the seventeenth and in two to begin on the twenty-first and twenty-fourth leaf-sheath respectively. By taking off ten leaf-sheaths seventy-six per cent. of the inwardly infected trees would be found and by taking off seventeen ninety-four per cent. Fifteen to seventeen was the number that came to be recommended for removal during the detailed examination to be described shortly. The number of leaf-bases on a palm depends on how often they are removed for economic purposes and how many are required at a time and varies from field to field and taluq to taluq. Even though a small number of infected trees would be missed, the omission was unavoidable. As it turned out, the inwardly infected palms were over a large area about 8 per cent. of those examined, and it would have been quite out of the question to have cut all trees so drastically as to have found out every case of disease.

To get information on a large scale a detailed examination of trees was made in the villages of Chikkala and Unagatla which are situated on the edge of the palmyra belt in the Kistna uplands where there is a great trade in sweet toddy for making *jaggery* for the sugar factory at Samalkota. Since the detection of the disease here in 1912, the number of dead trees had steadily risen and the area had increased to 1,059 acres. Great numbers of tappers migrated into this region annually from the central delta for the tapping season from March to June, and it is possible they brought the disease with them. At any rate their operations helped the disease to spread as the trees were so often handled and the tappers did not distinguish between infected and healthy palms in tapping. It was obvious that the extension of the disease into this belt would cause greater loss economically than in any other part of the area and that the operations here should be carried out more intensively. So great had been the opposition to the treating of outwardly infected palms in these two villages in 1913 that the Collector again suggested legislation to give authority to combat the disease. After a great deal of hard work in the villages the Special Tahsildar got a certain number of them done and towards the end of 1913 the Collector directed the Excise Officers not to issue any tapping licences during the coming season for trees situated in the infected area of these villages. At the beginning of the season in

1914 the agricultural and special officers concerned with the operations visited the villages and pointed out to the villagers that the disease was steadily spreading and would soon be into the heart of their tapping area and tha its progress could be checked if only they would co-operate in working against it instead of opposing the operations. It was consequently agreed that, if the villagers would cut and examine 17 leaf-bases from all the big trees and operate at once on all those found to be either internally or outwardly infected, then the prohibition would be withdrawn. To supervise the work all four Kistna revenue inspectors were concentrated in the two villages while the work was in progress, and an Excise Officer too remained to issue licences as soon as trees were ready. Work was finished before the tapping season really set in and tapping on trees known to be healthy proceeded. The result of the examination was as follows :—

Number of palms examined	Found to be diseased but with no external symptoms	Found to be diseased and showing external symptoms	Found to be dead
12,129	963	55	17

In May as the tapping season was on the wane the attention of the villagers was drawn to the results of this examination and to the likelihood of many of the palms that remained un-examined, because they were not ready or required for tapping, being infected and, if left alone, spreading the infection to the trees they wished to tap next year. They agreed to examine those as well, and all were examined with the exception of 450 palms infested with scorpions, snakes and "other devils": these the tappers would not climb. The complete results of both examinations were as follows :—

Number of palms examined	Found to be diseased but with no external symptoms	Found to be diseased and showing external symptoms	Found to be dead
20,831	1,265	72	13

These figures showed that six per cent. of the palms were infected without showing external symptoms, and that in this area the improved operations of cutting and burning dead and outwardly infected trees were dealing with

only six per cent. of the total number of diseased trees actually on the ground at the time.

In December 1914 when I visited Unagatla I had ninety-seven of the trees that had been examined in the previous March re-examined in the two worst infected fields and found eight diseased. The figures for the examination in March in the two fields were as follows :—

Number of palms examined	Number inwardly infected	Number outwardly infected	Number dead
(1) 375	240	6	1
(2) 1,387	218	8	1
1,762	458	14	2

The result of my examination of these eight trees led to the conclusion that (*a*) two had been unavoidably missed as the disease began from the fifth and the ninth leaf-base, respectively, counting from the lowest on the tree, and eleven and thirty-three leaf-bases respectively were penetrated, (*b*) two were probably avoidably missed as the lowest leaf-base in one and the third, though exposed, leaf-base in the other were spotted and thirty-three and fifteen leaf-bases respectively were penetrated, (*c*) two had not had all the diseased tissue removed as they had been recorded as inwardly infected and outwardly infected respectively, and (*d*) two were infected during or shortly after the examination as the lowest leaf-bases were spotted and eleven and twelve leaf-bases respectively were penetrated. Two of them were outwardly infected in December and the other six had no outward symptoms. They would all have been discovered at a re-examination. Considering that this was the first time the examination had been done on a large scale, the work, though by no means perfect, was satisfactory from the point of view of materially reducing the disease.

The Special Tahsildar of Godavari District attempted a similar examination in the upland infected areas in June. He was not, however, aided by the fortuitous circumstances which so assisted work in Kistna. In the thirteen small isolated infected areas in the uplands sweet toddy tapping was of small importance and of course the licences had already been issued where required early in the year. The cost of examination was accordingly defrayed by Government, and eleven of the areas were examined. After

hard, patient work in the villages the Tahsildar presented the following result :—

Number of palms examined	Inwardly infected	Outwardly infected	Dead
11,327	570	382	88

The figures showed that five per cent. of the palms were infected without showing external symptoms, and that in these areas the improved operations were dealing with only forty-five per cent. of the total number of diseased trees actually on the ground at the time. This explained the slow action of the operations hitherto in vogue in combating the disease, when action was delayed till a palm developed outward symptoms, and made clear the desirability and the possibility of carrying out such an examination.

In 1914 the area under operation remained unaltered in both districts. The gradual change in the method of operations first by dealing with palms that were outwardly infected and then with those that were inwardly infected rendered it a little difficult to compare the figures for the several years. The total number of diseased trees dealt with in both districts was 82,831 and this was a little higher than the previous year, but of them only 36,357 were dead, a considerable reduction on the figures for dead trees of the previous year, *viz.*, 58,469. During the monsoon there was a very protracted spell of warm wet weather which was favourable to the spread of the disease. At Tanuku thirty inches of rain fell on forty-three days between July and September as compared with thirteen inches on twenty-nine days in the same period of the previous year. On the whole, therefore, the figures for the operations were satisfactory. The disease was discovered towards the end of the year in two adjacent villages in Tuni Taluq just beyond the previously known infected area. All the 2,373 trees in the infected area of 650 acres were examined and 172 were found to be diseased. There was a recrudescence of the disease in Bunder Taluq where thirty-nine diseased trees were found. In this year a marked improvement in the carrying out of the operations was definitely noticed during my tour in December when I inspected twenty-two villages carefully and saw only eight outwardly infected and no dead palmyras. This inspection revealed a very different state of affairs to what existed even two years before and showed that the special staff had been working well and acting promptly on every external indication of disease. The work was now being conducted effectively.

1915 was even a wetter year than the previous one; for thirty-two inches of rain fell from June to August as against the average for forty years of seventeen and a half inches. The total number of diseased trees dealt with in both districts fell by 24,000 and the dead trees by 14,000. As the monsoon ceased in 1914 the staff in Kistna was urged to attempt in the coming dry weather a detailed examination of all trees in some of the worst infected areas and responded by undertaking to make an examination of every infected village. This work, begun in the end of November, was carried on till June 1915. It was an uphill task demanding constant exposure in the field during the hottest and driest part of the year and taxed their energies very considerably, but they brought it off successfully and it was an excellent piece of work. Registers were prepared for every one of the thirty-one infected villages showing the fields in which any cuttings had been made in 1913 and 1914. Every tree standing in these fields was examined and also every tree standing in an adjacent field and being within fifty yards of an infected tree. Excluding the villages classed as uninfected but which were still patrolled and including similar villages in which examination had to be made because parts of the adjoined infected fields of other villages, this work was carried out in forty-one villages. Besides this a re-examination was made in the Chikkala area and extended to 1,789 acres as compared with 1,059 of the previous year with the following result :—

	Examined	Inwardly infected	Outwardly infected	Dead
Main area	139,302	9,504	707	373
Chikkala area	22,198	525	105	55
TOTAL ..	161,500	10,029	812	428

The figures showed the great step forward that had been taken in trying to get level with the disease. According to the system in vogue before 1913 only 428 dead trees would have been dealt with : according to that in vogue in 1914, 1,240 would have been operated on or three times the number, whilst by means of this detailed examination it had been possible to deal with 11,269 infected trees or twenty-six times the number that would have been dealt with under the original system. It must not be thought that during this examination we made sure that every infected palm in the area covered had been dealt with. There would always be some cases that were actually

missed or in which the work was done imperfectly or which though standing beyond the fifty yards' limit were yet inwardly infected. It must also be admitted that this examination exposed the susceptible parts of a great many trees to the risk of infection. The risk of passing on infection by means of the tapper's knife was avoided by having the knife sterilized in boiling water or by passing it through a flame, after the tapper had operated on a diseased tree and before he climbed the next one. But the risk of infection by beetles and by splashing during rain had to be taken. We hoped that because of the known slow rate of spread of the disease and because the work was done mostly in the dry weather, the rate of spread would be much less than the rate at which the trees were being dealt with. This was a weakness of the method but, if we had tried to protect the exposed surfaces with Bordeaux mixture or any other fungicide, the time taken to do so effectively with the staff at our disposal would have prevented the examination of the large number of trees contemplated.

Early in 1915 the Kistna Tahsildar, who had been in charge of the central delta for the previous two years, had examined 33,578 palms there and found 3,039 inwardly infected. To introduce this practice, however, over the whole of the main infected area in Godavari District was the biggest problem the special staff had been faced with since 1909 when the present system was introduced. The staff was strengthened very considerably in numbers and the work was begun when the harvest was over at the end of November 1915 in the eastern delta and the end of December in the central delta and was finished by June 1916, when the rains came. In all 384 villages were worked over and the cutting and burning was done entirely at the people's expense. They were encouraged to take a personal interest in the operations and to give help. The following were the figures :—

Examined	Inwardly infected	Outwardly infected	Dead
968,492	44,391	10,145	14,207

The relative proportion of the groups of figures was quite different from that found in Kistna District but that was not unexpected over the main area with all its varying degrees of intensity of the disease in different villages and where the relative proportion of area lightly infected was far greater than in the area worked over in Kistna. It did demonstrate, however, the tremendous advantage of the new method.

1916 was a wetter year than ever and far exceeded the record for the past forty years. This lowered the cuttings for the second half of the year simply because of the difficulty of getting trees cut and burned in very wet weather. In the first half a re-examination of the Kistna area was made and a third examination of the Chikkala area. This time palms were examined within fifty yards of all dead and outwardly infected ones that had appeared since the previous detailed examination. The figures from December 1915 to June 1914 were as follows :—

	Examined	Inwardly infected	Outwardly infected	Dead
Main Kistna area	24,419	1,150	302	310
Chikkala area	8,864	167	71	12
TOTAL ..	33,283	1,317	373	322

In the Chikkala area there had been a continuous drop in the number of inwardly infected trees in the three examinations and also in the total number of diseased trees found in the year, *viz.*, 1,570 in 1914, 1,110 in 1915 and 301 in 1916, so that the detailed examination seemed to be having an effect in reducing the number of diseased palms in this area. In the main Kistna area too the number of inwardly infected palms was less in the re-examination. After finishing this work the staff cursorily inspected forty-three villages eliminated from control during the last few years and found diseased trees in four of them. These were taken under control again and another was added later on.

During 1917, 1918 and 1919 the general examination went on during the dry months and the number of diseased palms decreased except in 1918 when it suddenly increased. This was a bitter disappointment. Even though there had been a series of unusually wet years we hoped that the operations now had a greater influence on the disease than natural conditions. In Kistna District the disease appeared again in thirty-seven villages that had been given over to the supervision of the ordinary revenue staff in 1912, and in twenty-one other villages in Bhimavaram, Kaikalur and Gudivada, and a few stray cases were cut at Bezwada, Ellore and Masulipatam, while in Godavari District a few cases were cut in Polavaram. This shows the insidious character of the disease and how difficult it is to eradicate entirely from a village. From March 1918, when the number of infected trees was greatest, a special effort was made to get the disease again under control, and the general examination

in 1919, when the staff tried to find every diseased tree, showed that the number had fallen again to previous proportions. In December 1919 and January 1920 my assistant Mr. Sundararaman and I toured by separate routes through the worst infected villages of both districts. Altogether we saw under thirty dead or outwardly infected palmyras even though operations had been suspended for the previous two months. In former years during December and January there had always been a large number of diseased palms and we expected to see several hundreds. That so small a number of diseased trees was found on this tour of inspection was very encouraging and was an undoubted proof of the success of the operations.

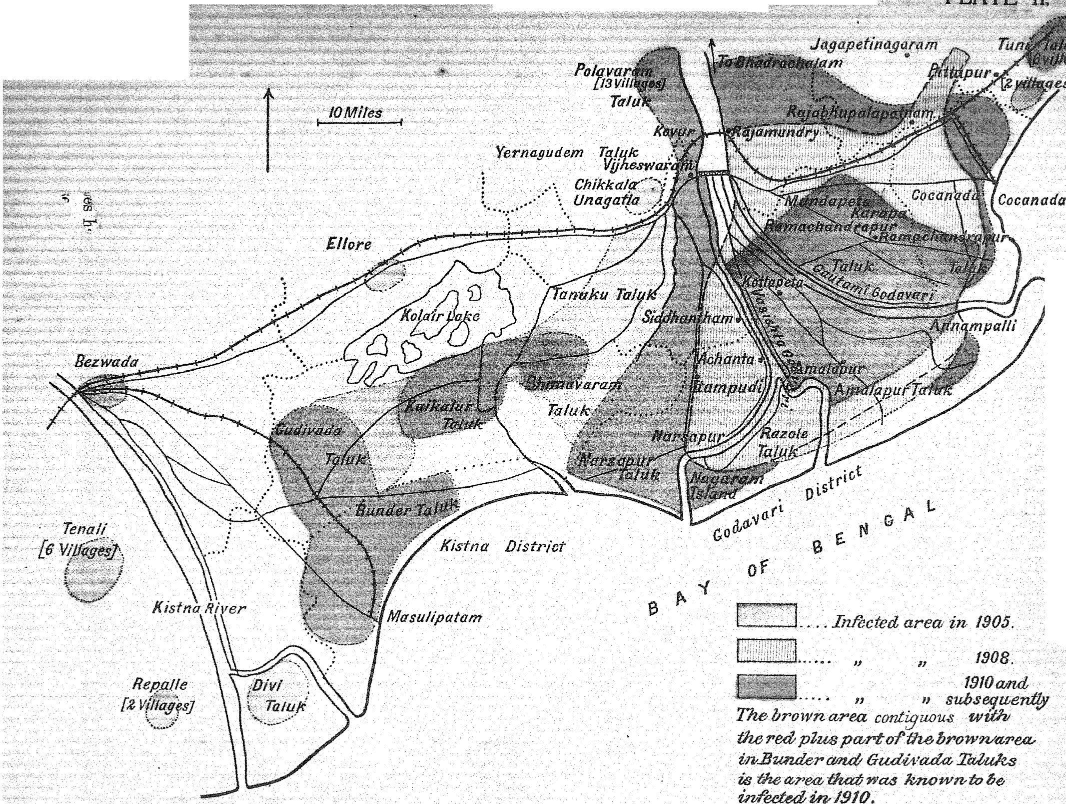
From November 1919 to March 1920 the operations were suspended at the instance of the Director of Agriculture in order that the staff might carry on a campaign of publicity before the application of the Pest Act to the disease. It was in connection with the attempt to have outwardly infected trees dealt with that we first suggested early in 1912 to take legislative power to cut compulsorily such trees, but Government declined to resort to compulsion till the need for it was much more clearly established. The operations went on accordingly relying on the tact and persuasiveness of the members of the special staff to overcome the difficulties. That they were successful in great measure has been shown in the discussion of the position of the operations from year to year, but they never induced any great body of the tree-owners to do the work spontaneously though they did persuade them to allow the cutting to be done at their (the tree-owners') expense. By 1919 a definite proposal for a local Pest Act was accepted by the Government of Madras, and at a special meeting at Pusa, where the subject was discussed, the last objection to such an Act was withdrawn and the way was finally opened for having it passed. Throughout the whole period of the operations there was one hope that never was realized to any great extent—the hope of interesting the tree-owners in the measures taken to combat the disease to such an extent as to get them to act for themselves. Had this hope been realized the special staff might have been withdrawn gradually and the people left to protect themselves against loss from the disease. Most people in the infected area knew about the disease and its symptoms but entirely depended on the official staff to deal with it. The next step was to stir up this interest. By the application of the Pest Act of 1919 dealing with diseased palmyras became a duty, and it seemed not unreasonable to believe that after people got accustomed to tackling the disease themselves they would come to realize that they could fight it without extraneous help. To ensure that every person in the infected area and around it did know sufficient about the methods

of dealing with diseased trees, his duties under the Act and the penalties for non-compliance, the special staff stopped the operations and devoted themselves to a publicity campaign. The fact of the operations being entirely stopped for four months seemed to have impressed the people that Government was in earnest. Pamphlets in the vernacular were written with illustrations given in colour and distributed to all the literate people directly and indirectly connected with the villages and small posters with an illustration of a diseased palmyra palm were posted in thousands on conspicuous places. To reach the great bulk of the tree-owners, who were illiterate, meetings were held in the villages where "sandwichmen" were sent round by day and lantern demonstrations were given by night. Verses were written and folksongs adapted and they were sung at festivals and fairs and mask dances were also a feature. Everything possible was done to excite interest and there is no doubt of the success of the campaign, and the credit is in great measure due to the energy and fertile brain of M. R. Ry. Rao Saheb V. Bhogappayya Sastry Garu, B.A., Special Deputy Collector on Palm Duty in Godavari and Kistna Districts.

In 1920 and 1921 when the complete operations were being carried on with the additional stimulus of the Pest Act, the number of diseased trees found remained low, being 16,500 in 1920 and 8,700 in 1921.

General review of the operations.

(a) *The numbers.* The earliest attempt in 1906 to deal with the disease over a limited area accounted for 40,000 dead palms. The number of dead palms cut during the 19 months, June 1907 to December 1908, *viz.*, 398,000, included many trees that had died from about June 1904 because it takes up to three years for all the leaves to wither, reckoning from the time the growing-point dies and the topmost leaf has withered. Consequently a considerable number of such cases would still be standing and be dealt with by the staff as they moved over the infected area. As mentioned on page 47, the intensity of the disease was greatest in 1908 when probably about 100,000 died, even though 183,000 were actually cut that year, the excess being cases that had died in the years immediately preceding. From 1908 to 1913 there was not much of a fall in the annual figures, this being due to the gradual perfecting of the operations, to trees being cut more promptly and to the area being better patrolled. From 1914 to 1917 there was a steady fall in the number of outwardly diseased and dead trees owing to the fact of 74,800 inwardly infected trees having been dealt with and cured. 1918 was a disappointing year because the number suddenly rose in all categories. However, there



Map of Kistna and Godavari Districts showing the infected area at different times.

was a considerable fall in 1919. In 1920 the Pest Act was applied and the numbers again fell both in that year and in 1921, the last year of the operations under review. From 1913 onwards 100,000 diseased trees in the early stages of infection had the diseased tissue removed and were restored to health during the examination of 2,800,000 apparently healthy palms growing in the vicinity of dead ones, and there can be no doubt that this had a great influence in quickly reducing the number of dead palms in the later years of the operations.

(b) *The area.* The area said to have been infected in the earlier years was given by Dr. Butler for August 1905 [1] and for the end of 1908 [2], and in a report to Government I gave the known infected area about the middle of 1910. The diagram (Plate II) shows in colour the different areas which were about 500, 1,200, and 1,800 square miles respectively. The extension in the northern part is fairly accurate but that towards the Kistna is inadequate in all three estimates. The information in the earlier estimates was got chiefly by a young member of the Agricultural Department whose home was in the Godavari delta, and it is likely that he had more detailed information about the Godavari where his home and his work were than about the Kistna District. The people in Tanuku and Narasapur Taluqs say they noticed it in 1903, the year of the cyclone, but the people beyond the Narasapur canal had no reason to report the presence of disease in those early days, thus it could only be located by actually seeing it and there was little or no touring done in the Kistna District before 1910 with the object of finding the extension of the disease. With later more accurate and detailed knowledge of the disease in this locality it seems more than probable that long before 1905 the disease had already crossed the Vasishta branch of the river, and that it had extended further into Kistna District by 1908 or by 1910 than is shown in the map. Early in 1910 cuttings were being made in Bunder Taluq around Masulipatam and from observations on the dead palms there I am certain the disease had been there for over three years before this date. Yet at the end of 1908 the disease had not been reported, nor was it known to exist there, by members of the department. In 1910 there were only two infected localities known between Masulipatam and the infected area in Narasapur and Tanuku Taluqs adjacent to the main infected area in Godavari District, *viz.*, Gudivada near the former area and Kaikalur near the latter. Hence I was inclined to think that the disease had been carried to Masulipatam by sea by human agency, which of course was quite possible. Subsequent information got by the

[1] Butler, E. J. *Agri. Jour. India*, Vol. I, pl. XX, p. 305.
[2] Butler, E. J. *l.c.* opposite p. 221.

Special Deputy Collector and Tahsildar, by one of my assistants and myself in extensive tours have led me to think that this explanation is unnecessary and that the disease could have travelled overland from the Godavari area. Granted that Kistna was infected earlier than was at first thought, and this seems very likely, the overland extension is quite feasible and in conformity with the facts of the then better known extension northwards in Godavari. The boundaries of the infected area about the end of 1912 enclosed a total area of about 4,000 square miles and, with the exception of two small extensions along the coast at the extreme ends, comprise the limits of the infected area. Beyond the railway line from Rajamundry to Samalkota and Cocanada the land is not irrigated but is upland dry land of a slightly undulating nature. Here the extension has been slow and the disease has generally occurred in the shallow depressions. From quite early in the operations efforts have been made to banish it from this tract and with success. It is now confined to two small tracts near the railway line and one further up the coast. In one of the former round Rajamundry the disease is of long standing and is still intense. This has come about because the tree-owners there have all along been difficult to persuade to do anything or allow anything to be done, but the stimulus of the Pest Act will no doubt have the desired effect. The tract in Peddapur consists of two very small areas where very few diseased trees are found now. The tract along the coast in Tuni Division comprised parts of two villages in 1914 but later was found to extend to eight. It was outside the area patrolled and had the disease for some time before it was discovered, but work is being concentrated on it now. Beyond the railway line from Rajamundry to Bezwada the disease, so far as is known, has not appeared except in a few villages on the right banks of the Godavari river once believed to be free but now known to be still infected. It has actually reached Bezwada and Ellore halfway between the two as an extension from the delta. The Kistna river is the boundary on the west side except for two small areas near Repalle and Tenali which were discovered in 1920 beyond the patrolled area. They are now being dealt with thoroughly.

(c) *Intensity of the disease.* The Kistna area was never so intensely infected as the Godavari one, with the exception of those parts of Tanuku and Narasapur Taluqs between the Narasapur canal and the Vasishta branch of the river, and has been more amenable to treatment by the operations. The disease is in several isolated areas and is nowhere severe except perhaps comparatively so in the river-side villages. Though not to the same extent as in Kistna the disease has disappeared throughout the Godavari District from many places where it once existed, and there are still five areas in which

it is severe though nothing like to the same extent as formerly, *viz.*, around Rajamundry, Mundapeta, Karapa, Vemavaram and Kottapeta. In general the disease has been pushed out and kept out of the uplands around the deltas except to a short distance on the banks of the Godavari river and in two other small areas, while in the deltas it has been thinned out especially towards the Kistna side and reduced in intensity.

(d) *The Cost.* The total expenditure in connection with the operations from 1906 to 1921 has been in round figures three lakhs of rupees or £20,000.

Results of the operations.

As in every fight against a disease it is well nigh impossible to make a complete estimate in figures of the good that has accrued, for besides the definite arithmetical value that can be put upon the individuals that have been cured, there remains the value of those that have escaped taking the infection because of the protection given them through the preventive measures, and any estimate of this value is more or less speculative. The capital cost of a palmyra in the deltas is about two rupees on the average. The benefits of the operations may be stated under four heads. (*a*) The value of the palms that have been cured, taking the number as a conservative estimate at 90 per cent. of 231,631 "inwardly" and "outwardly" infected palms operated on, is 417,000 rupees. (*b*) In 1907 and 1908 the number of dead palms cut includes the accumulation of several years, but in 1909 the bulk of the old standing cases had been removed and the operations would have had some little effect in reducing the yearly number of dead palms, so 100,000 may be taken as representing the maximum intensity of the disease in 1908. Now if the disease had continued steadily at that intensity then in the 15 years of the operations 1,500,000 palms would have died. But during that time 758,000 died,[1] so it can be said with confidence that 742,000 have been saved from infection and these represent a value of 1,484,000 rupees. (*c*) Again from the number of dead palms that were cut in 1907 and 1908 (398,000) it is clear that the intensity of the disease had been increasing rapidly since 1890 when it was first noticed, and there was no reason against its going on as rapidly to increase in the next 13 years. Besides, from an analysis of the figures from June 1907 when the operations began to the end of 1908, together with the knowledge that an interval of three and a half years may elapse between the death of the growing-point and the withering of all the leaves of

[1] Dead trees cut—calculated accumulation of dead trees in 1907—8 or 956,449—189,329= 758,120.

the crown, and that the disease arose to epidemic dimensions from a definite place in the Godavari delta about the year 1890, we can assume a simple progression in the rate of increase; then the figures for

	1908 would be	100,000
	1907	94,000
	1906	88,000
	1905	82,000
and for ½ of	1904	38,000
		402,000

the total of which is very near the figure for those actually cut, *viz.*, 398,000. At the same rate of progression for the next 13 years the figures for dead trees would be about 1,790,000 multiplied by some factor comparable to 100,000, the number of dead trees in the beginning of the period of 13 years under consideration. Of course, the actual number is purely speculative, but it does show the nature of the proportions to which the disease was approaching. The prevention of the disease in this case has a potential value that cannot be accurately estimated in money. (*d*) In conclusion, we can affirm definitely that the disease has been reduced from a grave menace (100,000 in 1908) to a controllable factor (8,700 in 1921).

Though the disease has been greatly reduced it is still dangerous and requires to be treated with caution. So many times has it been found, more especially in the earlier years, that when a village was put out of the sphere of operations after it had shown no diseased trees for one year, and sometimes too in later years, after an interval of two or three years the disease appeared again, sometimes because of re-infection from outside but undoubtedly also from the appearance of a small number of cases in which the fungus had been developing slowly, consequently the disease had appeared after a longer period than usual and had again started a nucleus of infection that spread the disease to surrounding trees requiring the village to be brought under the operations once more. Hence the operations under the Pest Act will have to be continued for some years longer (1) to reduce still further the amount of disease and (2) to deal thoroughly and expeditiously with the three or four small outbreaks that have occurred beyond the hitherto patrolled infected area.

It was the influence the Collectors of the two districts and their subordinate officers had with the people that made it possible for these irksome operations to be carried on, the members of the special staff being recruited wholly from the revenue branch of the district administration. For years there was no

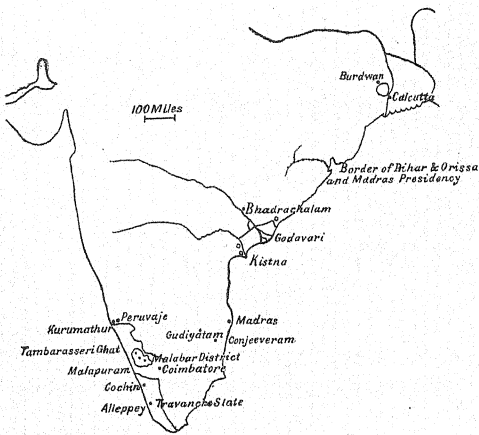
legal compulsion behind the staff and the only authoritative backing it had till 1919 was the order of the Collectors to the village officers to attend to this work. (Naturally it was Government in the first instance that decreed the operations, provided the funds for the special staff, and decided on the continuance of the work. But I am referring just now only to the actual working of the operations in the districts.) The revenue inspectors could not legally compel anyone to cut diseased trees, nor had they the right to enter on anyone's land and cut diseased trees. Everything had to be done with the acquiescence and the co-operation of the people, and naturally it took a considerable time to get them to agree at first to allow the work of cutting to be carried on at Government expense and then gradually at their own expense, especially as for some years there was no very apparent good result and as they believed the disease to be the scourge of a malign deity which there was little use trying to escape. It reflects credit on the members of the staff that they did so much for so long without any person's taking proceedings against them, and again that the people have been induced to carry on the work during the last two years under the Pest Act with only one prosecution. That the credit for carrying on the operations against this disease with the measure of success achieved is due to the special staff under the direction of the Collectors of the two districts is freely acknowledged. The Agricultural Department's activities consisted in elucidating the life-history of the fungus, devising and improving methods of combating the disease, and giving encouragement.

Occurrence of bud-rot of the palmyra in other parts of India.

One of the Special Tahsildars, who, when he was transferred from special duty on the palmyra disease operations in Godavari District, was posted to Bhadrachalam about 100 miles up the Godavari river, assured me that he had seen the disease among palmyras there. He knew the symptoms of this disease well and can hardly have been mistaken. The locality was difficult of access and I never had the opportunity of visiting it, nor did I manage to get specimens, so the observation was not confirmed. If it does exist there it suggests the interesting speculation that it may have come down the river and become epidemic in the delta after the completion of Sir Arthur Cotton's great irrigation scheme about 1854 had changed the delta and its environs into double crop wet land. Even[1] before the building of this irrigation system certain portions of the delta had been irrigated, but the area was small

[1] *Gazetteer of the Godavari District*, Chapter IV, p. 85.

and the channels were open only for about fifty days in the year during floods, so that the soil conditions of the delta were entirely changed after that date. If the speculation is correct the natural conclusion is that the palmyra in the deltas is doomed, and that, if it be left to the play of natural influences, it



will simply be a case of time before it becomes scarce. Even so the operations would have been well worth the labour and expense in order to prolong the time of decline and allow the coconut palm to be planted in sufficient numbers to replace the palmyra in the economic life of the people.

Outside the Godavari and Kistna area bud-rot in palmyra has been found in Peruvaje in South Kanara District on the West Coast and in Hooghly District of Bengal. Only a few cases were found in the former which is not far north of the area in Malabar where coconut palms are infected as will be mentioned later.

Occurrence in Bengal. While travelling by train to Pusa in 1921, Mr. S. Sundararaman, the Acting Government Mycologist of Madras, noticed between Calcutta and Burdwan in Bengal many palmyra palms dying and dead of a disease suspiciously like bud-rot. This was confirmed on examination. The following information has been acquired during tours made by a mycological

assistant from Pusa and a member of the Department of Agriculture of Bengal. The disease has affected palmyra palms only. It extends at its widest limits from Dankuni, ten miles north of Calcutta, to Gangpur near Burdwan, a distance of 50 miles, and from near Dwarhata to Inchura, a distance of 28 miles, while the infected area is approximately 700 square miles. Palmyras, however, are comparatively few in this region. Along with mango trees, bamboos and coconut palms they grow on the numerous slightly elevated pieces of land which are the village sites and between which stretch wide expanses of rice fields where palmyras do not occur on the raised boundaries between fields as they do in the Madras Presidency. Because of this discontinuous distribution of palms within the area it is perhaps unlikely that the disease will spread so fast or so persistently as it has done in the south ; Nor is the palmyra so valuable a tree in the Hooghly District either for thatching or for fuel, and it is said to be but seldom tapped for toddy. Economically the loss of palmyras is not thus of very much importance within the area at present infected, but it is a matter for consideration whether the damage would not be considerable were the disease to spread much or become epidemic. The number of dead trees is not known as no measures have yet been taken to deal with the disease. Assuming that the fungus runs its course as it does in Godavari and Kistna Districts, then from the appearance of palmyras in such villages as Pandua and Gurup I think the disease has been present for at least five years, and the people say that deaths have taken place in greater numbers for about that period. Considering the area now known to be infected, it is, however, probable that the disease has been present for a much longer time. Soon after the disease was discovered here the Madras Department of Agriculture had the palms of the maritime villages of the districts north of the infected area of Godavari District examined for a distance of 240 miles to the frontier of Bihar and Orissa, but no diseased palms were found. There is thus no thought of the disease having spread northwards by land into Bengal from the Godavari District. It is possible for it to have been carried by sea but the infected area is too large to get reliable information as to where it started. On the other hand, it is possible that the disease is endemic. Its presence was brought to notice by an officer who was closely connected with the disease in Madras Presidency, and it was till then unknown to the Department of Agriculture though the fact that palmyras were dying in considerable numbers in this and other parts of the delta and its environs was known as early as 1912. This shows that the disease has hitherto caused no appreciable loss, and that the people are so accustomed to palmyras dying in small numbers as to pass it without comment. All this rather

indicates that the disease has been present for a considerable time, than that it is of recent introduction.

Occurrence of bud-rot in the coconut palm.

In Godavari and Kistna Districts the number of coconut palms, *Cocos nucifera* Linn., is few indeed compared with that of palmyras. Round Amalapur and Ramachandrapur, however, they are increasing and are being planted in gardens of fair size. Very few cases of this disease, however, have occurred amongst them. In this area, compared with the 700,000 palmyras that have been found to be diseased since January 1910, when I took over the post of Government Mycologist, Madras, not more than 200 coconut palms have become diseased. When the fungus is placed on the pale yellow soft susceptible part of the bud of a coconut palm it penetrates as readily as in a palmyra. The relative freedom from disease of this palm is not therefore due solely to resistance in the palm but mainly to the structural character of the bud and to the fact that the palm is less handled than the palmyra. The leaves of the coconut palm grow out at an acute angle to the imaginary upward prolongation of the stem, gradually bend over and ultimately hang down. Quite early as the leaf-base becomes gradually exposed its protective covering becomes so thickened as to be only with difficulty and usually not at all penetrable by the fungus. On the other hand, the leaf-base of the palmyra always remains in its original position, literally as a sheath, one to one-and-a-half or even two feet long, and its protective covering does not thicken materially for many months, till it becomes exposed by the removal of the leaf-bases below it. From the time a coconut leaf protrudes from the bud and expands, to the time it is at right-angles to the stem and its leaf-base is non-infectible, a period of 10 months usually elapses; whereas from the time a palmyra leaf expands till the leaf-base is exposed and is non-infectible, a period of three years may elapse. During these intervals and of course for some time before when it is in the bud each leaf-base is infectible. There is a stiffness about the palmyra with its more rigid trunk and the broad simple laminæ of its leaves that must cause the softer inner tissue of the parts of the bud to be momentarily exposed as the crown sways in the strong winds of the monsoon and so allow of the possibility of infection to be relatively greater. The coconut palms in the deltas are seldom tapped for toddy and are climbed only for harvesting the nuts and for removing the leaves for thatching purposes and making mats. At neither time is the bud cut. Palmyras, on the other hand, are frequently tapped and are always prepared for this by cutting off the lower leaf-bases to trim the tree; the leaf-bases

are also removed at short intervals for fuel and to some extent for fibre. Thus the palmyra is handled more frequently and in such a manner as both to expose it to infection and to cause infective material to be carried to it.

Occurrence of bud-rot of the coconut palm in other parts of the Madras Presidency.

Early in 1913 Mr. T. Bainbrigge Fletcher, then the Government Entomologist of Coimbatore, brought to notice the occurrence of bud-rot in coconut palms in a village near the foot of the Tambarasseri ghat in Malabar District facing the West Coast of South India, and the cause was determined by Shaw and Sundararaman[1] to be *Phytophthora palmivora* Butl. A special staff of revenue inspectors was organized to search for the disease in this part of the district to determine its extent and to have the diseased palms operated on or destroyed as was required. During the monsoon which was heavy in this locality they examined gardens and marked infected trees to be dealt with in the ensuing dry weather. In the course of the work extending over two years the disease was found in 102 villages in seven taluqs. Calicut, Chirakkal and Kurumbranad had the greatest number of infected villages, *viz.*, 44, 27 and 22 respectively, while Ernad and Kottayam had 5 and 2 respectively. In one village of Ponnani Taluq and another of Cochin a few diseased palms were found and these, as far as was discovered, were far away from the main infected area. The symptoms on coconut palms were similar to those on palmyras, *viz.*, the dying of the central leaf and in succession those below it, the appearance of characteristic rows of spots on the pinnæ of the leaves and on successive leaf-bases and the rotting of the bud. As far as possible trees with either of the outward symptoms were dealt with but very great opposition was encountered to cutting those with rows of spots on the pinnæ. As far as the experience went, the coconut palm did not recover nearly so readily as the palmyra under similar drastic surgical treatment. The number of trees dealt with was as follows :—

Half-year ending December 1913	877	palms	cut.
June 1914	1,680	,,	,,
December 1914	688	,,	,,
June 1915	1,183	,,	,,

Besides which, 75 that were located were dealt with by the ordinary revenue staff soon after. The total number was thus 4,503 in about two years. The disease was very widely spread in that part of Malabar District

[1] Shaw, F. J. F. and Sundararaman, S. The Bud-rot of Coconut Palms in Malabar. *Ann. Myc.*, Vol. XII, pp. 251-262, 1914.

but was nowhere intense. The fruit of this palm is so valuable that it was practically impossible to get the people to apply the system of detailed examination of palms growing within fifty yards of the diseased ones as was done with the palmyras in Godavari and Kistna Districts. The location of the disease and the small number of trees attacked seemed to indicate that the disease had been there for many years and that it was not increasing. The comparatively costly special staff was accordingly disbanded and the work was entrusted to the ordinary revenue staff of the district. Illustrated leaflets in English and Malayalam were distributed in large numbers describing in detail the symptoms of the disease and the remedial measures to be adopted. The revenue staff was also impressed with the necessity of giving early intimation of the disease becoming acute in any locality. Since then only a small number of trees have been cut and nowhere has the disease become severe.

The disease has also been found on coconut palms at Conjeeveram in Chingleput District, at Gudiyatam in North Arcot, at Ernaculam in Cochin State and at Alleppey in Travancore State. In all these places very few diseased trees were found (under fifty in any place). Conjeeveram and Gudiyatam are small isolated areas hundreds of miles from the other known infected areas. While of the extent of the disease in Cochin and Travancore States the writer has no information. The fact that the disease exists without doing much damage over a considerable range of the West Coast where there is a continuous belt of coconut palms from south to north seems to indicate that it is endemic in South India. This disease was also found on young coconut palms in a garden in the town of Madras. The garden owner had himself brought the seedlings from a village within the infected area in Malabar and planted them in his garden. Fortunately when the disease appeared he asked advice from the Agricultural Department. It was at once diagnosed and all the palms were destroyed. Neither before nor since has the disease appeared in the vicinity of Madras. This is a proved instance of the disease having been carried for a distance of four hundred miles by human agency.

Spread of the disease.

So far as has been demonstrated the fungus is carried from tree to tree by means of tappers, and rhinoceros beetles, *Oryctes rhinoceros* Linn. The rhinoceros beetle is the commonest of the insects that visit the palmyra. The adult beetle alone is found in living crowns boring into the stalks and laminæ of the younger leaves near the apex of the crown and feeding on the tender tissue. The earlier stages, egg, grub and pupa, are met with only in dead and rotting crowns and in rotting stems and, of course, also in garbage

elsewhere. The habits of the beetle are thus such that it could be a carrier of the disease from palm to palm. Besides it is also likely that during the monsoon the spores are splashed from the spots on an expanding leaf to surrounding palms. The transference of spores and mycelium of the fungus from an infected tree to a healthy one has been made by means of a platinum needle, a scalpel, the leg of a rhinoceros beetle, the finger and a tapper's knife, and trees have become infected in all cases.

In ordinary conditions the tapper's knife is one of the chief means of spreading the disease. When he cuts a tree in any stage of disease either during the operations or in the course of his business he is likely to get the fungus on his knife or his hands and to leave it on an infectible part of the next tree he climbs. This has been done in many villages while demonstrating to the assembled tree-owners that the disease could be spread in this way. The tapper inserted his knife into a spot on a leaf-base and then drove his knife a few leaf-bases deep into a crown or cut off some leaf-bases. The tree was marked and was not climbed till our next visit. Invariably the palm had produced the characteristic spots on the leaf-bases a few months afterwards when it was examined in the presence of the villagers. For example, one palmyra was pierced in two places. When examined the leaf-bases were found to be diseased as follows :—counting from below upwards leaf-bases Nos. 1 to 4 were free, 5 had a spot on the inside of one limb, 6 had a knife-cut and a spot surrounding it, 7 to 15 had spots, 16, 17 and 19 had knife-cuts one within the other and from them had started a new set of spots that increased rapidly in size to the 26th and 27th leaf-bases where the spots were from three to four inches in diameter, 28 had a smaller spot and 29 had a small spot on its outer surface, while 30 to 33 had no spots. After thus removing the leaf-bases for examination the tree recovered and was healthy for the next three years. In recognition of this tappers were taught to sterilize their knives after cutting a diseased palmyra either by passing the knife through the flame of the burning crown or by rubbing it well with dry earth, and during the detailed examination of trees growing round diseased ones the tappers, under the supervision of the revenue inspectors, were trained to flame their knives or to place them for a minute in hot water.

In July 1911 the crowns of five young palms were enclosed in cages made of fine wire mesh. A rhinoceros beetle was caught and made to crawl over a culture of the fungus that was discharging zoospores. It was found on examination that it had a considerable amount of mycelium and sporangia as well as zoospores on its under surface. It was placed on the crown of one of the palmyras in the cage. This was repeated with other

beetles on other three palms. The same was done with two pairs of palm weevils which were placed on the crown of the fifth palmyra. None of them made any attempt to bore but crawled up and down the cage till they died. The experiment was repeated: only this time a part of a leaf-sheath with a pale yellow lower part was removed from each palm and the beetle imprisoned in its place. More weevils were not available at the time. At the end of September the five palms were examined. The fungus had developed in four but not in the fifth. From two to eight leaf-sheaths were penetrated. Three of the weevils were recovered dead in the position in which they were placed while two had disappeared. The diseased leaf-sheaths and four more were removed and trees were alive and healthy several years afterwards. The cages were removed and placed on five other palmyras and the experiment with rhinoceros beetles repeated with similar results except that all five became infected. The diseased leaf-bases were completely removed and those five remained free from disease afterwards. It was done in a field in which diseased palmyras had never occurred, and I did not wish the palms to die lest the people would be annoyed and disagreeable with regard to the operations, hence the disease was removed from them in order that they might not die. The fact that I wanted to demonstrate was whether an infected rhinoceros beetle could carry the disease to a healthy palm and it was done. Beetles have been caught and examined several times but only once has the fungus been cultivated from one. The beetle exists in considerable numbers and many palms are bored, so I believe it plays an appreciable part in the dissemination of the disease.

The red palm weevil, *Rhynchophorus ferrugineus* Oliv., found on the palmyra but more common on the wild date palm, passes all its stages on the palm. It is generally believed that the weevil attack follows that of the beetle, the holes made by the latter offering favourable spots for the weevil to lay eggs in. I have found it seldom and then on young palmyras only when, after the leaf-bases have been cut, they began to bleed a sweet juice. Its numbers and habits thus lead one to believe it plays an insignificant part, if any, in spreading the disease.

The disease travels slowly though persistently and the three means of dissemination discussed, namely, tappers, rhinoceros beetles and rain splashing on the expanding infected leaves, together with occasional long distance transport by human agency seem sufficient to account for the facts.

II. INOCULATION EXPERIMENTS WITH *PHYTOPHTHORA PALMIVORA* BUTL. ON *BORASSUS FLABELLIFER* LINN. AND *COCOS NUCIFERA* LINN.

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Series **A** was carried out with the fungus taken direct from the palm and pure as tested by the microscope, while series **B** was done with pure cultures of the fungus.

A. The crown of a palmyra in which the central leaf was becoming pale was cut off in Rajabhupalapatnam in the morning of 17th July 1910 and brought to Samalkota in the afternoon. The outer leaf-sheaths were removed till clean young spots were exposed on the inner leaf-sheaths, and several of the spots were cut out and placed in a moist chamber. Next morning the spots had a copious growth of mycelium on their surfaces. Small pieces of aërial mycelium were examined microscopically both before and after producing sporangia and appeared to be a pure growth. When the material was placed on a glass slide and irrigated the numerous sporangia burst and within an hour most of them had discharged their zoospores. This was the material used for inoculating palms Nos. 1 to 14. The water from such cultures was carefully washed into a watch glass and a drop used for Nos. 15 to 17. Young palms, the visible part of whose trunks varied from three to twelve feet in height, were selected in a field in Bhimavaram near Samalkota, the only criterion of choice being that they were small enough to be operated on from the ground or from a tapper's short ladder. The outermost dry leaf-sheaths were removed and the inner partially dry ones had the attachment of one limb to the stem severed, while the attachment of the other remained intact. Usually three or four leaf-bases were treated, thus giving access to the pale yellow living leaf-sheaths within. These half attached leaf-sheaths were held aside, the inoculating material placed on the outer side of the first

uncut leaf-sheath, and the half-attached leaf-sheaths replaced. A cord of fibre was tied round to keep the leaf-sheaths in position. In a few cases a fold or two of the fibrous material of the leaf-sheath was wrapped round and wetted but, as a matter of fact, in the result this made no difference. All the operations were done to one palm before proceeding to the next. The surfaces of the newly exposed leaf-sheaths on which the inoculating material was placed were not sterilized. But as the leaf-sheaths fit closely together and were exposed for only a few seconds, it is probable that they did not have any of the inoculating organism. The palms grew in a place in which it was known that diseased trees had not occurred within a radius of three miles. Spots from the inner leaf-sheaths of all of the palms that became infected developed, when incubated, aërial mycelium, sporangia and zoospores identical with those from the original palm. Seventeen palms were inoculated and all became infected. Three of them died but two had palm weevils in them so are doubtful. These two had exhuded a sweet juice from the stem where the limbs of the leaf-sheaths had been cut and so attracted the weevils. Seven controls did not become infected. All the diseased tissue as well as one or two more leaf-sheaths was removed from the palms in making the observation. Subsequently no diseased palm appeared in the field up to 1920.

Nos. 18 to 32 were done at Itampudi, and Nos. 33 to 50 at Kottapeta, both of which were severely infected villages. The infective material was similar and the method was also in most cases similar. A sterilized tapper's knife was sometimes used to place the fungus on the palm as a demonstration to the villagers. Sometimes the point of the knife which is blunt was laid against the leaf-sheath, at others the knife was driven into the crown for one or two inches. In a number of cases the limbs of the lower leaf-sheaths were not cut to get access to the inner ones but they were pulled down sufficiently far. No. 51 was a coconut palm done on the Samalkota Farm and described in Experiment III on page 67. Table IV gives a summary of the salient features of the inoculations. Of fifty palmyras inoculated, forty-eight became infected, of which seven died and two others that died had palm weevils in them. None of the nineteen controls developed symptoms of disease. The only coconut palm inoculated at this time also died. All the symptoms of disease seen in the field were reproduced, *viz.*, the death of the central leaf or group of leaves, the central leaf or group of leaves could be pulled out easily and had a discolouration and rot at their torn ends, spots on the leaf-sheaths, rows of spots on the laminæ of the leaves, and a rot of the bud which in advanced cases was stinking.

TABLE IV.

Results of inoculation of Phytophthora palmivora *Butl. on fifty palmyras and one coconut palm*

No.	Height of trunk in feet	Date of inoculation	Inoculating material	Date of observation	Interval of days	No. of leaf-sheaths attacked inwards	Central shoot dead	REMARKS
1	7	18–7–10	Myc. sporangia	18–8–10	30	2	..	The spotted leaf-bases were removed and the trees remained healthy. There was no diseased palm in this field up to 1920, the date of the last observation.
2	3	18–7–10	Do.	18–8–10	30	2	..	
3	9	18–7–10	Do.	18–8–10	30	2	..	
4	3	18–7–10	Do.	18–8–10	30	6	..	Do.
5	9	18–7–10	Do.	18–8–10	30	1	..	Do.
6	4	18–7–10	Tissue with Myc. sporangia	18–8–10	30	3	..	Do.
7	9	18–7–10	Myc. sporangia	17–8–10	30	10	+	Weevils present. Do.
8	4	18–7–10	Do.	18–8–10	30	5	..	Do.
9	9	18–7–10	Do.	17–8–10	30	11	+	Weevils present. Do.
10	10	18–7–10	Do.	17–8–10	30	10	+	Do.
11	4	18–7–10	Tissue with Myc. sporangia	18–8–10	30	5	..	Do.
12	4	18–7–10	Myc. sporangia	18–8–10	30	4	..	Do.
13	9	18–7–10	Do.	18–8–10	30	9	..	Do.
14	10	18–7–10	Do.	18–8–10	30	2	..	Do.
15	12	18–7–10	Do.	18–8–10	30	4	..	Do.
16	3	18–7–10	Zoospores	18–8–10	30	2	..	Do.
17	6	18–7–10	Do.	18–8–10	30	3	..	Weevils present. Do.

TABLE IV—*contd.*

No.	Height of trunk in feet	Date of inoculation	Inoculating material	Date of observation	Interval of days	No. of leaf-sheaths attacked inwards	Central shoot dead	REMARKS
18	10	29-7-10	Zoospores	6-9-10	39	8	..	Destroyed during observation.
19	9	29-7-10	Do.	6-9-10	39	5	..	Do.
20	9	29-7-10	Myc. sporangia	6-9-10	39	6	..	Do.
21	10	29-7-10	Do.	6-9-10	39	4	..	The spotted leaf-bases were removed and on 23rd March 1912 all were healthy.
22	8	29-7-10	Do.	6-9-10	39	2	..	
23	6	29-7-10	Do.	6-9-10	39	4	..	Do.
24	8	29-7-10	Do.	6-9-10	39	3	..	Do.
25	7	30-7-10	Do.	6-9-10	38	4	..	Do.
26	11	30-7-10	Do.	1-12-10	124	8	..	Do.
27	4	30-7-10	Do.	1-12-10	124	..	..	Did not become infected.
28	8	30-7-10	Do.	19-12-10	142	11	+	
29	10	30-7-10	Do.	1-12-10	124	..	..	Did not become infected.
30	6	30-7-10	Do.	1-12-10	124	1	..	23rd March 1912. The infected leaf-sheath was dry and the fungus dead.
31	11	30-7-10	Do.	1-12-10	124	5	+	23rd March 1912. Dead.
32	7	30-7-10	Do.	1-12-10	124	9	+	Do.
33	8	9-8-10	Do.	2-11-10	85	..	+	
34	7	10-8-10	Do.	1-9-10	21	10	+	Leaf-sheath incised at inoculation.
	8	10-8-10	Do.	1-9-10	21	7	..	Crown cut off.

36	4	10–8–10	Do.	1–9–10	21	3	..	The spotted tissue removed and tree remained healthy.
37	11	10–8–10	Do.	1–9–10	21	2	..	Crown cut off.
38	6	10–8–10	Do.	1–9–10	21	8	..	Do.
39	8	10–8–10	Do.	1–9–10	21	2	..	The spotted leaf-bases were removed and the trees remained healthy for several years.
40	5	11–8–10	Do.	1–9–10	21	6	..	
41	7	11–8–10	Do.	1–9–10	21	6	..	Do.
42	5	11–8–10	Do.	1–9–10	21	5	..	Do.
43	6	11–8–10	Do.	1–9–10	21	4	..	Do.
44	8	11–8–10	Do.	1–9–10	21	6	..	Do.
45	5	11–8–10	Do.	1–9–10	21	4	..	Do.
46	6	11–8–10	Do.	1–9–10	21	4	..	Weevils present. Do.
47	10	11–8–10	Do.	1–9–10	21	3	..	The leaf-sheath Do. incised at inoculation.
48	12	11–8–10	Do.	1–9–10	21	8	..	Weevils present. Do.
49	9	11–8–10	Do.	1–9–10	21	3	..	Do.
50	8	10–8–10	Do.	25–11–10	107	..	+	Symptoms appeared between the 2nd and 25th November.
51	8	25–8–10	Do.	22–11–10	89	..	+	Coconut palm. [Expt. III. Table V]

A few examples may be given in detail.

No. 34. The four central leaves had become yellow.

The outer covering leaf-sheaths had

(1) four spots (3 × 2 in.), ($1\frac{1}{2}$ × 1 in.), $\frac{1}{4}$ in. and $\frac{1}{8}$ in.

(2) two spots (5 × 4 in.), $\frac{1}{4}$ in. and $\frac{1}{8}$ in.

Leaf-sheaths inwards from the inoculated place

(1) the inoculated spot was (5 × 2 in.), and an adjacent spot (1 × $\frac{3}{4}$ in.)

(2) one spot (3 × 2 in.), and two lower down ($\frac{1}{2}$ × $\frac{3}{4}$ in.), and ($\frac{1}{4}$ × $\frac{1}{8}$ in.)

(3) one spot ($2\frac{1}{2}$ × 2 in.)

(4) two spots ($2\frac{1}{2}$ × 1 in.), and (1 × 1 in.)

(5) one spot (4 × 1 in.)

(6) one spot ($3\frac{1}{2}$ × $2\frac{1}{2}$ in.), a little below the level of that on 5.

(7) one spot (4 × 3 in.)

(8) two spots (1 × 1 in.), and (1 × 1 in.)

(9) two spots (1 × 1 in.), and (1 × 1 in.), one had a good web of mycelium.

These were at the insertion of the leaf-sheath and the tissue of the stem was discoloured and softer, but the leaves still within the bud were not discoloured.

No. 10. The three central leaves had become yellow.

The penetration of the leaf-sheaths was much the same as in No. 34, the discolouration and softening had extended into the bud leaves as well as being in the stem tissue.

No. 14. The infective material had been placed in the axil of the leaf. At the time of observation there was no outward symptom of disease. Two leaves towards the inside were penetrated and the soft tissue of the stem was discoloured and softened at some distance below the growing-point. Sections showed the presence of the fungus in the stem tissue and on incubating a piece mycelium and sporangia were produced. Cases of this kind have been found in nature and this is probably the reason for the occasional death of leaves lower than the central leaf as the first symptom.

No. 13. A thin slice of tissue with mycelium and sporangia was held on the upper part of the leaf-sheath and a fine jet of water played on it. At the time of observation there were no outward symptoms of disease. On the inoculated leaf were several spots at various heights penetrating through a

number of leaf-sheaths varying from two to nine in any one line. The fibre of the ninth leaf-sheath was discoloured and from the part of the discoloured area but not in line with any other line of spots a series of spots penetrated to the central expanding leaf going through its petiole.

No. 38 is typical of the others. Spots were found on one leaf-sheath towards the outside and on eight towards the bud in line. The spot on the outer leaf-sheath was 5 × 2 inches.

No. 1 had one spot 5 × 4 inches.
,, 2 ,, ,, ,, 3 × 2 ,,
,, 3 ,, ,, ,, 1 × 1 ,,
,, 4 ,, ,, ,, $1\frac{1}{2} \times 1$,,
,, 5 had three spots $1 \times \frac{3}{4}$, 1×1 and $\frac{3}{4} \times \frac{1}{4}$ adjacent to one another and one spot on the edge of the other limb almost touching the others.
,, 6 had one spot $2\frac{1}{2} \times 1$ inches.
,, 7 ,, ,, ,, $1 \times \frac{1}{4}$,,
,, 8 ,, ,, ,, $\frac{1}{4} \times \frac{1}{4}$,,
,, 9 was clean and free from spots.

The eleventh leaf-sheath enclosed the bud and its lamina was the topmost expanding leaf. The spots on Nos. 5 and 6 had a felt of mycelium.

B. The palmyra and coconut palms used for inoculation had never been exposed previously to infection from the fungus. They were grown in Coimbatore which was fifty miles from the nearest infected area in Malabar District and was separated from it by a range of forest-clad hills running up to 5,000 feet. The trunk was measured from the ground level to the insertion of the lowest leaf-sheath of the crown and represents the visible part of the trunk. The cultures were made by plating aërial mycelium that had copious sporangia from a spot on a leaf-sheath and each culture was from a single sporangium. The controls were treated in exactly the same way as the inoculated palms except that no fungus was placed on them. The infective material for the inoculations was usually a small piece of mycelium from a subculture producing sporangia copiously and it was transferred by a platinum needle. The point of inoculation was usually recorded by a grease-pencil mark. The date given for the observation of the first symptom in Table V. is that on which the symptom was unmistakable.

TABLE V.

Inoculation experiments with Phytophthora palmivora *Butl.*

	No. on palm	Part of the palm inoculated	Date of observing first symptoms	Interval of days	Infected	Dead	First symptom
Experiment I	1	Leaf-sheath	21–12–13	15	+	+	C
Palmyra to palmyra	2	Do.	21–12–13	15	+	+	C
Trunks 2 to 8 ft. high	3	Do.	21–12–13	15	+	+	C
Date of inoculation, 6th	4	Do.	21–12–13	15	+	+	C
December 1913	5	Do.	21–12–13	15	+	+	C
	6	Central leaf	21–12–13	15	+	+	C
	7	Do.	9– 1–14	34	+	+	R
	8	Do.	..	..	—	..	..
	10	Do.	26–12–13	20	+	+	R
	9	Controls	..	..	—	..	..
	11 to 18	Do.	..	..	—	..	..
Experiment II	9×	Central leaf	..	..	—	..	..
	10×	Do.	11– 8–14	13	+	..	R
Palmyra to palmyra	11×	Do.	..	..	—	..	..
Trunks up to 4 ft. high	12×	Do.	13– 8–14	15	+	..	R
Date of inoculation, 29th	13×	Do.	11– 8–14	13	+	+	R
July 1914	14×	Do.	11– 8–14	13	+	+	R
	15×	Do.	..	..	—	..	..
	16×	Do.	10– 9–14	43	+	..	C
	17× to 20×	Controls	..	..	—	..	..
Experiment III	31	Central leaf	15– 8–14	19	+	..	R
	32	Do.	15– 8–14	19	+	..	R
Palmyra to coconut palm	33	Do.	6– 8–14	10	+	+	C
$2\frac{1}{2}$ years old	34	Do.	15– 8–14	19	+	..	R
Date of inoculation, 27th	35	Do.	15– 8–14	19	+	..	S + P
July 1914	36	Do.	..	..	—	..	..
	37	Do.	15– 8–14	19	+	..	R
	38	Do.	15– 8–14	19	+	..	R
	39	Do.	..	..	—	..	..
	40	Do.	..	..	—	..	..
	41–46	Controls	..	..	—	..	..
Trunk 8 ft. high 25th August 1910	..	Leaf-sheath	22–11–10	89	+	+	C
	..	This is a coconut palm No. 51 of Table IV.					

R = Row of spots on the expanding lamina.
C = Central leaf drying.
S = Spot on the leaf-sheath.
P = Spot on the petiole.
L = 3rd, 4th, 5th leaves drying.

TABLE V—*contd.*

	No. on palm	Part of the palm inoculated	Date of observing first symptoms	Interval of days	Infected	Dead	First symptom
Experiment IV	20	Leaf-sheath	9–9–14	25	+	+	C
	21	Do.	25–9–14	41	+	+	C
Palmyra to coconut palm	22	Do.	9–9–14	25	+	+	C
2½ years old	23	Do.	6–9–14	22	+	+	C
Date of inoculation, 15th	24	Do.	29–9–14	45	+	+	C
August 1914	25	Do.	17–9–14	33	+	+	C
	27	Do.	10–9–14	26	+	+	C
	30	Do.	..	..	—	..	..
	31	Do.	..	..	—	..	..
	32	Do.	..	..	—	..	..
	34	Do.	17–9–14	33	+	+	C
	35	Do.	13–9–14	29	+	+	C
	36	Do.	..	..	—	..	..
	37	Do.	..	..	—	..	..
	38	Do.	..	..	—	..	..
	47–52	Controls	..	..	—	..	..
Experiment V	1	Control	..	..	—	..	..
	2	Leaf-sheath	..	..	—	..	..
Coconut palm to coconut	3	Do.	3–1–14	29	+	+	C
palm	4	Do.	21–1–14	47	+	+	C
8 years old	5	Do.	4–4–14	120	+	..	S
Date of inoculation, 5th	6	Do.	..	..	—	..	..
December 1913	7	Central leaf	21–12–13	16	+	..	R
	8	Do.	21–12–13	16	+	..	R
	9	Do.	21–12–13	16	+	..	2R
	10	Control	..	..	—	..	..
Experiment VI	19	Central leaf	12–8–14	16	+	+	R
	20	Do.	15–8–14	19	+	+	R
Coconut palm to coconut	21	Do.	15–8–14	19	+	+	R
palm	22	Do.	..	..	—	..	..
1½ years old	23	Leaf-sheath	15–8–14	19	+	+	R
Date of inoculation, 27th	24	Do.	15–8–14	19	+	+	C
July 1914	26	Do.	17–9–14	52	+	+	C
	27	Central leaf	15–8–14	19	+	..	R
	28	Do.	17–9–14	52	+	+	R
	30	Petiole	15–8–14	19	+	..	P
	29	Controls	..	..	—	..	..
	43–45	Do.	..	..	—	..	..
Experiment VII	1	Central leaf	4–9–14	38	+	+	C
	2	Do.	..	..	—	..	..
Coconut palm to palmyra	3	Leaf-sheath	3–8–14	6	+	+	L
trunks 2–4 ft. high	4	Do.	10–8–14	13	+	+	C
Date of inoculation, 28th	5	Do.	5–8–14	8	+	..	C
July 1914	6	Central leaf	4–9–14	38	+	+	C
	7	Do.	4–8–14	7	+	+	C
	8	Do.	20–8–14	23	+	+	C
	9–12	Controls	..	..	—	..	..

R = Row of spots on the expanding lamina.
C = Central leaf drying.
S = Spot on the leaf-sheath.
P = Spot on the petiole.
L = 3rd, 4th 5th, leaves drying.

Experiment I. The culture was got from a palmyra in Gurusanapalli, Cocanada Taluq, on 20th November 1913 on quaker oat agar. For all except No. 10 the second subculture on quaker oat agar was used and for it the second subculture on French bean agar. The trunks of the palms were from two to eight feet high. In Nos. 1 to 6 where the leaf-base was inoculated the infective material was placed on the unwounded pale yellow surface of that part of the leaf-base which lay within the bud and which was exposed sufficiently by carefully but firmly pressing the leaf-bases apart. In Nos. 7, 8 and 10 the fungus was placed within the folds of an unexpanded leaf. Fifteen days after inoculation the central leaf was drying in Nos. 1 to 6 and the lower leaves gradually died in succession, and on 5th January 1914 they were dissected. The central leaf or leaves could be pulled out of the crown easily and their lower ends were rotting. Leaf-bases had the characteristic spots and some were also rotting. The tissue of the stem in the region of the growing-point instead of being of a pale cream colour was brown, soft and rotting. The fungus was present in the leaf spots and in the stem tissue and pure cultures were made from leaf-bases whose position was not nearer than the second within the inoculated leaf-base. In Nos. 7, 8 and 10 a fold of the unexpanded central leaf was inoculated. In Nos. 7 and 10 a row of spots was produced at the point of inoculation and the central leaves of No. 7 died. These two palms were dissected on 28th January 1914 and 5th January 1914 respectively and showed bud-rot. No. 8 did not become infected by 30th April 1914, nor did any of the nine controls.

Experiment II. The culture was got as in experement I but on French bean agar. The third subculture on French bean agar was used. The trunks varied up to four feet in height. In Nos. 9 to 12 the infective material was placed within the fold of the unexpanded central leaf and in Nos. 9 and 12 a small plug of wet cotton wool was inserted between the folds a little above the point of inoculation. A row of spots was formed on the expanding leaf in Nos. 10 and 12. As the leaf expanded the spots dried up and no other part of the palms became infected. Nos. 9 and 11 did not become infected. In Nos. 13 and 14 the infective material was placed between the central leaf which was just protruding from the bud and the expanding leaf, and in the latter a plug of wet cotton wool was placed. The central leaf in both palms produced a row of spots and the central group of leaves in both dried. On 29th August 1914 they were dissected and had bud-rot. In Nos. 15 and 16 the infective material was placed between the central leaf which was expanding and the next one and a plug of wet cotton wool was placed just above in the former. Forty-three days afterwards the central leaf of No. 16 dried

and other three leaves dried within three days. On dissection the palm showed bud-rot. No. 15 did not become infected, nor did the controls up to December 1914. In these two experiments *P. palmivora* Butl. produced in palmyras the characteristic spots on the leaf-base and on the lamina and after the fungus had reached the delicate tissue on the apex of the stem a bud-rot set in.

Experiment III. The culture was the same as for experiment II and the third subculture was also used. The palms were two-and-a-half years old. In Nos. 32, 33 and 39 the infective material was placed within the folds of an unexpanded leaf. In Nos. 31, 34, 37, 38 and 40 it was placed on the outside of the unexpanded leaf. In No. 35 it was washed down into the bud and in No. 36 it was placed between two petioles. In ten days the central leaf of No. 33 was drying and in nine days more three leaves outside it were dried. On dissection the palm showed bud-rot. In nineteen days No. 32 had a row of spots extending almost across the lamina. Nos. 31 and 34 had a row through three double segments of the folded lamina, No. 37 across half the breadth of the lamina and No. 38 across two-thirds, while No. 39 did not become infected. No. 35 had spots on the leaf-base of the expanding leaf and on two leaf-stalks while No. 36 did not become infected. The central leaf of Nos. 31, 32, 34, 37 and 38 had grown out into the air and was expanded. The spots dried up and produced no external mycelium though pieces placed in a moist chamber did. A coconut palm whose trunk was six feet high was inoculated on the Samalkota Farm on 25th August 1910 and dissected on 22nd November 1910. The inoculative material was aërial mycelium bearing sporangia from the leaf-sheath of a palmyra and was not an artificial culture. The central group of leaves was dead and was pulled out easily showing a soft rot at the torn ends; the leaf-bases had the characteristic spots; the leaf-bases, bud leaves, and the upper soft part of the stem were involved in a rot that had a nauseous smell, symptoms typical of the disease in the field. Other three palms in the group were unaffected and were still healthy years afterwards.

Experiment IV. The culture was the same as for experiment II, and the third subculture was used. The palms were two-and-a-half years old. The infective material was placed on the leaf-base of the second leaf in Nos. 21, 22, 34 and 35 of the third in Nos. 20, 23, 24 and 25, of the fourth in Nos. 27, 30, 32, 36 and 37, and of the sixth in No. 31, while in No. 38 it was placed on an injured place at the base of the crown. The central leaf of all but six of them dried at various dates indicated in Table V. The central leaf of No. 20 was dry after twenty-five days and five more leaves were dead eight days after: that

of No. 22 was dry after twenty-two days and three days after two more were dried. The others were similar. Once the central leaf had died the others below it died within a few days. They were all dissected and had bud-rot. Six did not become infected and the six controls remained healthy. In these two experiments *P. palmivora* Butl. from the palmyra produced in coconut palms the spots on the leaf-sheath and on the pinnæ, and after the fungus had reached the delicate tissue of the stem a bud-rot set in.

Experiment V. Cultures on French bean agar and on quaker oat agar were got from a coconut palm in Kurumathur in Malabar District on 14th November 1913. For Nos. 2 to 7 the first subculture on quaker oat agar was used and for Nos. 8 and 9 that on French bean agar. The palms were eight years old. The infective material was placed on the leaf-base in Nos. 2 to 6 and on the fold of the unexpanded leaf in Nos. 7 to 9 on 5th December 1913. On 3rd January 1914, twenty-nine days after inoculation, the central leaf of No. 3 was pale and came out when pulled lightly, on 31st January 1914 the next leaf was drying, on 26th February 1914 two more leaves were drying, but by 4th April 1914 no more leaves were dead and the palm was dissected. On 21st January 1914, forty-seven days after inoculation, the central leaf of No. 4 was pale, on 31st January 1914 the next two leaves were drying, on 14th February 1914 two more leaves were dried and the shoot had fallen over and was hanging down. On 26th February 1914 there was no further change and the palm was dissected. On 4th April 1914 there were no symptoms of disease on No. 5 so the palm was opened up. The leaf-base inoculated had a spot three inches in diameter extending to three-quarters of its thickness while the fibrous portion of the leaf-base next within had several small spots on a discoloured area four inches in diameter. Nos. 3 and 4 had spots on the leaf-bases and the bud was rotten. Nos. 7, 8 and 9 each had a row of spots extending over several segments sixteen days after inoculation and the last hab mycelium with sporangia on the surfaces of the spots. By 26th February 1914 two more rows of spots had developed on Nos. 7 and 9 and three on No. 8. On 4th April 1914 the diseased tissue was removed from Nos. 5, 7, 8 and 9. Nos. 2 and 6 were examined but had not become infected. The two controls were healthy and all but the two that were destroyed were healthy in July 1922.

Experiment VI. The culture was the same as for Experiment V on French bean agar and the third subculture was used. The palms were one-and-a-half years old. Nos. 19, 20, 22 and 27 were inoculated on the central unexpanded leaf, Nos. 21 and 28 on the under surface, No. 30 between the first and second petioles, No. 26 on the third leaf-base and Nos. 23 and 24

on the fourth. Nos. 19, 20, 21, 27 and 28 each produced a row of spots on the pinnæ of the central leaf, and two months after inoculation Nos. 19, 20, 21 and 28 were dead. No. 30 had a spot on each of the two petioles but the spot came through to the other side of each petiole as a discolouration only and no further symptoms appeared. In Nos. 24 and 26 the central leaf dried first, one early, the other later, and the other leaves in quick succession and both palms died. The first symptom on No. 23 was the presence of two rows of spots on the central expanding leaf, one extending from the midrib to the edge, and the other from the midrib almost to the edge but half an inch below the level of the other row. This was unexpected as the infective material had been placed between the fourth and fifth leaf. The palm was dead on 30th September 1914. No. 22 did not become infected and the five controls were healthy at the end of December 1914. The dead palms all had a soft rot which had gone so far that the leaf-bases were brown, soft and rotten, so that the spots were not distinctly differentiated. In these two experiments *P. palmivora* Butl. from a coconut palm produced in coconut palms spots on the leaf-sheaths and the pinnæ and after the fungus penetrated the bud a bud-rot set in.

Experiment VII. The culture was the same as in Experiment V on French bean agar and the third subculture was used. The palms had trunks from two to four feet high. The infective material, a minute piece of agar with mycelium and sporangia, was placed in Nos. 1, 2, 6, 7 and 8 between the protruding leaf and the expanding leaf, in Nos. 3 and 4 between the third and fourth leaf and in No. 5 between the sixth and the seventh leaf. No. 2 did not take the infection within the five months of observation. The others showed the drying of the central leaf as the first symptom except No. 3 where the first symptom was the drying of the third, fourth and fifth leaves almost simultaneously. No. 4 had three leaves dried and No. 3 twelve on 13th August 1914, sixteen days after inoculation, while No. 1 had six and No. 6 eight on 17th September 1914, fifty-one days after inoculation. The central leaf was pulled out easily, spots were found one after the other in line, and the bud had a soft stinking rot. In No. 5 sixteen days after inoculation the three uppermost expanded leaves were drying, the central leaf had a spot on its petiole, five leaf-bases had spots and the soft part of the tissue of the stem had a soft rot but it had not actually involved the growing-point though it had come within half an inch of it. In No. 7 on 27th August 1914 two leaves were dried up, spots were present in line on the folded leaf, the petiole of the expanding leaf and on the leaf-bases of the next two leaves. There was also a spot on the folded leaf two inches below the point of inoculation

and the region of the growing-point was rotting. In No. 8 on 20th August 1914 the central leaf was drying, seven days later the protruding leaf came away on pulling lightly and its base was discoloured and rotten. It was dissected and the region of the growing-point was rotting as well as the leaf-bases of the next three leaves. The four controls remained healthy till the end of December 1914. This experiment shows that *P. palmivora* from a coconut palm will infect the palmyra and that after it has invaded the soft tissue on the apex of the stem a bud-rot ensues.

In these experiments care was taken to incubate sufficient material from each experiment to make sure the fungus was present and to get it into culture again for comparison. Sections were also taken in all cases to demonstrate the presence of the fungus within the respective tissues.

Butler proved that *Phytophthora palmivora* would infect the living leaves of the palmyra, while Shaw and Sundararaman proved that it would infect living leaves of the coconut palm and kill seedlings. These experiments confirm and amplify those of Butler, Shaw and Sundararaman, definitely show that *P. palmivora* will lead to the death of both the palmyra and the coconut palm, that it can pass from one to the other palm and that all the symptoms of bud-rot have been re-produced in both palms as a result of infection by this fungus. When the fungus penetrates the soft tissue of the stem below the growing-point the tissue is killed and a rot ensues. Other organisms then begin to work and carry on the rot at a greater rate than the fungus does till the whole central part of the crown is involved. That the fungus is the primary cause of the rot and the controlling factor in the epidemic form in South India is all that is claimed. From the economic point of view these other organisms are of secondary importance and have not been worked out. These results meet completely the criticism of Sharples and Lambourne[1] regarding the cause of bud-rot of palms in India.

[1] Sharples and Lambourne. Observation in Malay on Bud-rot of Coconuts. *Ann. Bot.*, Vol, XXXVI, pp. 64—69, 1922.

CONTENTS

LIST OF ILLUSTRATIONS

PLATE

TEXT-FIGURES.

STUDIES IN INHERITANCE IN COTTON, I.

HISTORY OF A CROSS BETWEEN *GOSSYPIUM HERBACEUM* AND *GOSSYPIUM NEGLECTUM*

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I. INTRODUCTION.

Attempts to increase the value of the cotton plant grown in India or the value of the cotton produced, by means of the crossing of different species or different varieties of the cotton plant, date almost from the beginning of serious work on cotton improvement in the early years of the present century. And it is natural that this should have been a favourite way of tackling the problem, for there are such a large number of species grown in India, each with its special advantages and disadvantages, that hardly any species can be considered as really satisfactory from both the grower's and the merchant's point of view. For instance, the types derived from *Gossypium neglectum* are high yielding, high ginning, and easily grown, but are nearly always poor in staple—the poorest in fact of any types of cotton actually in cultivation. *Gossypium indicum*, though of excellent staple, yields poorly and has a low ginning percentage. *Gossypium herbaceum*, though cultivated over large areas, usually requires a long growing period and is hence difficult to grow, while its staple varies very widely, and in the cultivated types good staple seems to be almost always joined to low ginning percentage. It appears, at first sight, in fact, that if the valuable characters attached to each of these species could be combined with those derived from one of the others, an almost ideal cotton plant for almost any area could be obtained.

The crossing in question is not, however, nearly so simple, as appears at first sight, for all the varieties are polymorphic, being made up of a number

of distinct strains which have a different botanical and agricultural value. This polymorphic character of the crop, together with the fact that natural crossing occurs in the field to a limited extent, has two effects. It makes selection of the best of the strains a more easily applied method of improvement, and it makes the effect of crossing less easily determinable, especially when a parent is itself a hybrid between several of the strains in the crop. Hence, though a very large number of crosses were made in the years before 1907, they were almost all abandoned as giving types of too inconstant and too unsatisfactory a character, very soon after they had been produced. And, as a result, selection of the most valuable strains in the crops ordinarily grown has been almost exclusively relied upon for cotton improvement in the last twelve or fourteen years.

But it is obvious that the limits of improvement by selection alone, however carefully done, are very narrow. The best types can be isolated and grown pure, and this is usually an immense advantage, for the growing of a mixture of strains of unequal value is always unprofitable. But beyond the limit set by the types already existing, or the chance occurrence of a valuable mutation in the growing crop, no breeder can go without actual crossing of types.

Hence, as has already been said, crossing has been often attempted but the results of the crosses have rarely been carried so far as to get into actual cultivation. In the early days before 1907 when a large number of crosses were made in a somewhat haphazard and empirical fashion, the most important result was to show that the various Indian cottons cross freely with one another, and that, as would be expected, the immediate effect of crossing is to lead to considerably increased vigour in the plants. These facts were soon discovered by the workers on the subject, and as a result, in Bombay for instance, during the years between 1901 and 1907 [1] crosses were made between the *broach*, *kumpta*, and *goghari* varieties of *Gossypium herbaceum*, the Dharwar-American, and the Cambodia varieties of *Gossypium hirsutum* and others. These were combined in almost every possible way with the object of inducing variability and then selecting desirable variations. But although careful selection was made for a number of years the crosses obtained usually proved unprofitable. The necessary precautions such as the protection of the plants from natural crossing were not taken, and the crosses were made without recognizing that each variety of cotton is itself a mixture of many types. Moreover, mass selection was adopted, too early, even before the strains obtained were fixed

[1] Kulkarni and Kottur. Improvement of Cotton in the Bombay Presidency. *Bull. No.* 70. *Dept. of Agri., Bombay* (1915).

Generally, therefore, the result was neither to obtain the improved types desired, nor even to settle the question as to what are dominant or recessive characters when different types of cotton are crossed with one another.

The above remarks refer to the crosses made in Bombay, but the same negative results seem to have been obtained in other parts of India. In the Central Provinces a number of hybrids were produced at Nagpur and Akola in 1905 and 1906, but the fate of these is unknown. And a similar statement might be made with regard to such crossing work as was done in every province in India. The hybrids which ever passed out into general use were few, and they themselves were by no means pure. Among these may be noted the so-called "Kumpta Cross"—a hybrid between two strains of *kumpta* cotton (*Gossypium herbaceum*) made in 1901 and No. 1027 A. L. F. at Navsari in the *broach* cotton area, a type produced in 1901 by crossing the *kumpta* and *goghari* varieties of *Gossypium herbaceum.* Using similar methods, a cross between *bani* (*Gossypium indicum*) and *deshi* Lahore (*Gossypium neglectum*) termed the "Sindewahi Cross" seems to have successfully entered into general cultivation in the Central Provinces.

The first published work on the principles which lie in the basis of the successful crossing of Indian cottons for agricultural purposes was that of Fletcher,[1] who, basing his conclusions on Bombay experience, stated that, fineness, length and colour of the lint are dominant in the crosses he made, that yellow colour in the flower is dominant over white, and that fuzziness in the seed is dominant over nakedness. About the same time Balls[2], whose work in Egypt since that time has been of very great importance on all questions in relation to the growth and development of cotton, published his first work. The conclusions to which he came will be referred to later in considering the heredity of each factor discussed in the present paper. The work of Fyson[3] followed, and was based chiefly on crosses between a *Gossypium herbaceum* (*jowari*) and a *Gossypium neglectum* (*jari*). He found that the shape of the leaf (broad-lobed and narrow-lobed) and the colour of the flowers (white and yellow) appear to segregate on Mendelian lines, yellow colour being dominant over white and the narrow lobing of the leaf being dominant over the broad lobing. Again he judged, though he did not prove, that fuzziness of the seed segregates as a Mendelian character, and that "so far as two generations

[1] Fletcher. Mendelian Inheritance in Cotton. *Jour. Agri. Sci.*, Vol. II, p. 281 (1907).

[2] Balls. Note on Mendelian Heredity in Cotton. *Jour. Agri. Sci.*, Vol. II, p. 216 (1907); also Mendelian Studies of Egyptian Cotton. *Jour. Agri. Sci.*, Vol. II, p. 347 (1908).

[3] Fyson. Some experience in the Hybridising of Indian Cotton. *Mem. Dept. Agri. Ind.*, *Bot. Ser.*, Vol. II, No. 6 (1908).

showed, length and fineness of the lint were dominant over the short and rough woolly nature, and the habit of the bolls opening widely dominant over that of opening a little."

The work of Balls between 1907—09 is interesting because it deals with Egyptian cotton, and hence with a species different from that with which most of the work in India has been done. He found natural crossing taking place and studied the second generation (F_2) of these crosses. He observed that long staple was completely dominant over short, thus confirming Fletcher's and Fyson's observations on other species of cotton. The inheritance of the colour of the flowers was more complex, and he was not able to elucidate its character completely. The time of ripening (*i.e.*, earliness or lateness of the type) seemed to be a Mendelian character, while "the fact that many of the most important commercial qualities are dominant Mendelian characters presages considerable difficulty in preparing improved types." Later on, he studied a large number of additional characters in crosses between American (*Gossypium hirsutum*) and Egyptian (*Gossypium barbadense*) cotton, and his conclusions may be summarized as follows.

(*a*) The following characters are completely dominant :—

(1) Tallness of the main stem over shortness.
(2) A long leaf over a short leaf.
(3) A slightly incised leaf over a deeply incised leaf.
(4) A broad angle between leaf lobes over a narrow angle.
(5) A long petal in the flower over a short petal.
(6) Large seed over small seed.
(7) Long lint over short lint.

(*b*) The following characters are incompletely dominant :—

(1) A red spot at the base of the leaf over a leaf without this spot.
(2) Yellow colour over white colour in the flower petal.
(3) A red spot at the base of the flower petal over a petal with no spot.
(4) Yellow colour over white colour in the anthers.
(5) Brown colour over absence of colour in the lint.

(*c*) No definite conclusion was reached with regard to the heredity of the following characters :—

(1) Hairiness of the plant.
(2) Shape of the stipule.
(3) Roughness and glandulation of the boll.
(4) Fuzziness of the seed.
(5) Colour of the fuzz.
(6) Distribution of lint on the seed.

We shall see later how far the author's investigations on an entirely different cross confirm these observations.

Leake's work, which was begun in 1904, and was published in a series of papers from 1908 to 1914, was based in the first instance on a much more careful examination of the manner of growth of Indian cottons than had hitherto been made, and on three crosses made between pure lines of—

(1) *Gossypium arboreum* (*narma* cotton) and *Gossypium neglectum* (white-flowered *deshi*).

(2) *Gossypium indicum* (*bani* cotton) and *Gossypium neglectum* (white-flowered *deshi*).

(3) *Gossypium herbaceum* (*broach* cotton) and *Gossypium neglectum* (white-flowered *deshi*).

The principal work was done with the first of these as the cross between *herbaceum* and *neglectum* cotton tended to give infertile seed, and that between *indicum* and *neglectum* showed signs of weakness in the *indicum* parent. The characters studied were (1) the colour of the corolla and the presence of a spot at the base of the petal; (2) the presence or absence of red colouring matter in the sap; (3) the leaf factor; and (4) the type of branching and the length of the growing period previous to flowering. Two of these characters will be discussed fully later* in connection with the author's own crosses, namely, the colour of the corolla and the leaf factor. With regard to the other characters named above, it may be stated that presence of a spot at the base of the petal is completely dominant over its absence, that the red colour in the sap is a complex of two factors, redness and yellowness, and these segregate on Mendelian lines, and that the type of branching appears not to be inherited as a definite Mendelian character. Leake confessedly limited his papers to a discussion of the vegetative characters of the cotton plant and promised another memoir on the commercially valuable portion of the crop. This has not, however, as yet appeared.

Taking all together, therefore, the work hitherto done would seem to indicate that in making crosses between types of cotton, the inheritance is largely of a simple Mendelian character though there are a number of qualities, which are either non-Mendelian or else of a more complex kind than that ordinarily found. Apart, therefore, from the wish to obtain improved types of cotton suitable for a particular tract, it seemed also of importance to ascertain how two varieties of cotton, in pure line, behaved with regard to some of these apparently complex characters. The progress made on these lines is the chief subject of the present memoir.

* See pages 85 and 106.

II. THE TYPE OF COTTON DEMANDED FOR THE *KUMPTA* AREA.

The interest of the whole question of cotton crossing for the author has lain on the fact that he has been long employed in the attempt to obtain improved types of cotton for the area which now grows the variety of *Gossypium herbaceum* known as *kumpta* cotton. Work has continued for many years on the lines of selection of the best and most suitable types for that area from the existing crop, and with considerable success. A full account of this work has been given in another memoir.[1] But it quickly became apparent that progress by this method here, as elsewhere, was limited, and further advancement towards the ideal type of cotton plant for this tract could obviously only be made by introducing the missing qualities in the best strains of the local cotton by crossing with other types.

The type of cotton which appears most suited to the Kumpta tract has been already described (*loc. cit.*). The essential points are a relatively rapid flowering and fruiting type of plant, and hence a plant which is, adopting Leake's classification, essentially sympodial. This has been secured by the isolation of a pure strain known as Dharwar No. I. This has the qualities of quick growth, of early flowering, and rapid fruiting which are needed in the Kumpta tract. On the other hand, it has the following disadvantages.

(1) Though the ginning percentage is high (28·5) as compared with that of most strains of *kumpta* (25·5), yet it is low compared with many other types of cotton grown in India, and even of many types of *herbaceum* cotton. Thus *broach* cotton, a *herbaceum* type grown in Gujarat, has normally a ginning percentage of 32, and some strains go considerably higher. The *neglectum* cottons nearly always approach a ginning percentage of 36 to 38 and so on.

It was obviously desirable that this faculty of high ginning should be introduced into the *kumpta* cotton if this can be done without loss of the yielding power and staple of Dharwar No. I.

(2) The colour of the *kumpta* cottons is always dull white with a tinge of red, and no selection has enabled this character to be overcome. Now the Gujarat *herbaceum* and the *neglectum* cottons generally are very white, and if this could be secured without losing the faculties which give *kumpta* its special value for the area in which it is grown, a much more valuable product both to the cultivators and to the market will be secured.

(3) The tall erect character of the plant should be emphasised in any cross that is made, or in other words the sympodial character of Dharwar

[1] Kottur. *Kumpta* Cotton and its Improvement. *Mem. Dept. Agri. Ind., Bot. Ser.*, Vol. X, No. 6 (1920).

No. I should be emphasised in the cross, as this means earliness, an exceedingly important quality for the Kumpta tract.

Thus a type is to be secured by crossing which has all the good qualities of Dharwar No. I, and, in addition, has a considerably larger ginning percentage in the *kapas*, a better colour in the lint and a tendency to emphasise the earliness of the plant. To obtain these advantages easily there are only two Indian types with which it is obviously worth while crossing the Dharwar No. I strain of *kumpta*. These are (1) strains of high ginning Gujarat *herbaceum* cottons, of which possibly the *goghari* type is the most suitable, and (2) strains of *neglectum* cotton, chiefly from the high yielding, high ginning types from Berar or Khandesh. Between these two the decision is easy, for while the Gujarat *herbaceums* are desirable in other respects, they are all monopodial in character and hence bushy in growth and late in flowering and fruiting. The *neglectum* cottons, on the other hand, give equal ginning percentage, have an equally good colour, and are erect essentially sympodial plants.

It was hence decided to proceed with the crossing of the pure line of the *kumpta* variety of *Gossypium herbaceum* known as Dharwar No. I and a pure line of *Gossypium neglectum* isolated by the author from the narrow-lobed, white-flowered type of Sholapur cotton (which is essentially identical with that from Khandesh), and it is an account of this cross and its behaviour that forms the remainder of the present memoir.

III. THE PARENTS OF THE CROSS.

The parents of the proposed cross may first be described.

(1) The Dharwar No. I strain of *Gossypium herbaceum* was isolated by the author in 1913 from the *kumpta* cotton grown at Dharwar. It has been described in detail in the memoir previously referred to (pages 254-261) and this description therefore need not be again repeated. But its principal characters can be indicated as follows :—

- (*a*) The stalk of the cotyledons is green throughout, as is the case with all *herbaceum* cottons.
- (*b*) The number of monopodia on each plant varies from 0 to 5, with the mode at 3. 79·7 per cent. of the whole plants examined have either 2 or 3 monopodia per plant.
- (*c*) In leaf character, the plant may be shortly described as one with short and broad lobes, with a leaf factor—to use Leake's term—of about 1·4.
- (*d*) The flower is yellow, and the petals are from 22 to 39 millimeters in length, the mode standing at 28 to 30 millimeters.

(*e*) Nectaries are present both on the leaves and on the bracteoles.

(*f*) As already stated, the colour of the cotton is dull white with a tinge of red.

(*g*) The ginning percentage varies from 26 to 29, with mode at 28. Only one per cent. of plants had a ginning percentage as high as 30.

(*h*) The mean seed weight was 0·057 grammes, and was, as we shall see, almost identical with that of the other parent.

(*i*) The staple of the lint ranged from 0·8 inch to 1·1 inch with a mode of 0·9 to 1·0 inch.

(2) The strain of *Gossypium neglectum* used for this cross has not been described before, and hence a somewhat detailed account must be given of such of its various characters as have importance for the present experiments. It belonged to the narrow-leaved, white-flowered variety of this species which has been called *Gossypium neglectum* var. *rosea* by Gammie.[1] This forms, as is well known, the most highly ginning element in the mixture commonly grown in the regions of India growing *neglectum* cottons. A picture of a typical plant is shown in Plate I.

The characters important for our present purpose are as follows :—

(*a*) The stalk of the cotyledons is red at the tip, like all *neglectum* cottons, differing thus from Dharwar No. I with which it is to be crossed.

(*b*) The number of monopodia on each plant varies from 0 to 3, the most frequent number being 2. The number of monopodia on 1,000 plants in 1919-20 was as follows :—

Number of monopodia	Frequency
0	11
1	191
2	598
3	200
4	0

It will be seen that the number of monopodia is rather less than on the Dharwar No. I strain with which it is crossed, though both of them would be classed as sympodial cottons.

(3) The leaf characters show extreme difference from that of the other parent of the cross, previously described, and the leaves would be described as long and narrow-lobed, with a leaf factor of 3·5. Exactly what this means

[1] Gammie. The Indian Cottons. *Mem. Dept. Agri. Ind., Bot. Ser.*, Vol. II, No. 2 (1907).

PLATE I.

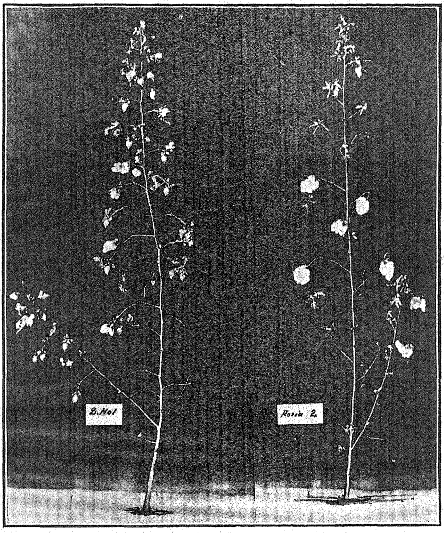

Fig. 1. Parents of the cross.

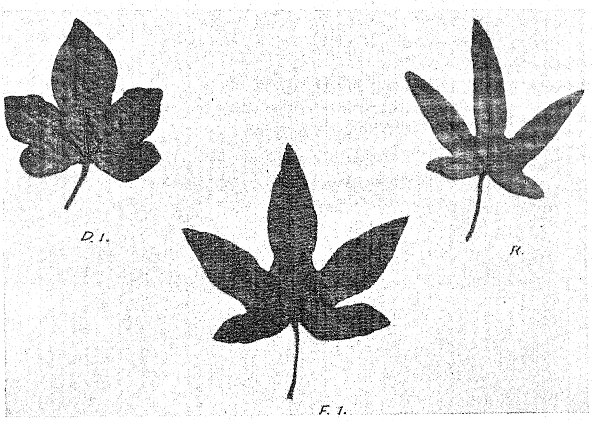

Fig. 2. Leaf form of the parents of the cross and of the F_1 generation.

is shown by the figures of typical leaves of this strain shown in Fig. 1. They are all primary leaves, and represent either the 5th, 6th, 7th or 8th formed

BREADTH (m.m.)

LENGTH (m.m.)

	13 15	16 18	19 21	22 24	25 27	28 30	31 33	34 36	37 39	40 42
37–39					6	13	DHARWAR I			
40–42						58	44			
43–45					5	61	74	19		
46–48		ROSEA				31	81	69	5	4
49–51	3						11	6	3	4
52–54	5	9	10					2	1	1
55–57	26	13	6							
58–60	20	48								
61–63	35	34								
64–66	35	90	20							
67–69	5	35	5							
70–72		58	13							
73–75		18	17							
76–78			8							

FIG. 1.

on the main stem of the plant. As there is considerable variation in the leaves in different parts of the plant and between large leaves and small, the above mentioned leaves have been kept throughout for all our measurements.

Taking these leaves, and measuring the length and breadth of the middle lobe of the leaf on many plants, the contrast between the character in the *Gossypium neglectum* (*rosea*) under discussion is well shown in the following correlation table. It will be seen that all the leaves of Dharwar No. I have a lobe with no greater length than 52 mm., while none of the *rosea* type are shorter than 51 mm. Likewise the middle lobe of the whole of the leaves of Dharwar No. I type has a breadth exceeding 25 mm., while all those of the *rosea* type are under 21 mm. Generally speaking, the following table shows

These figures indicate that there is an almost exactly similar distribution of the frequency of various ginning percentages in the progeny for plants of varying ginning percentages. It may be taken, therefore, that in ginning characters we have in the *Gossypium neglectum* (*rosea*) type used for crossing, a pure line in this variety. (Fig. 2.)

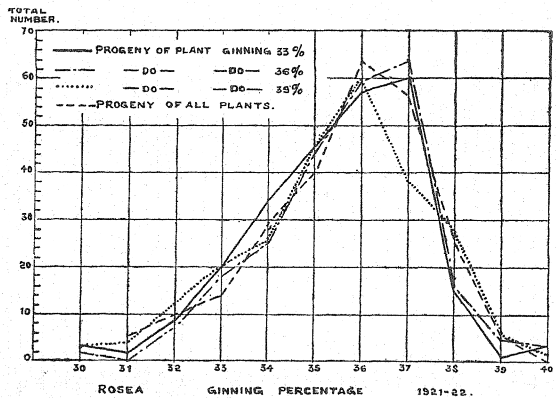

FIG. 2.

Taking all together, therefore, we have two parents which are very similar as to the general character of the plant, and as to the seed weight. They are, on the other hand, markedly contrasted as to (1) the colour of the stalk, (2) the shape of the leaf, (3) the colour of the flower and the length of the petal, (4) the presence of nectaries both foliar and extra floral, (5) the colour of the lint, (6) the ginning percentage of the *kapas*, and (7) the staple of the lint. The following table shows these characteristic differences, which had (previous to the crosses being made) been shown to be constant within known limits, under self-fertilization, during several seasons :—

	Gossypium herbaceum Dharwar No. I	*Gossypium neglectum rosea*
(1) Colour of the stalk	Wholly green	Red at the tip
(2) Shape of leaf	Short and broad-lobed. Leaf factor 1·7	Long and narrow-lobed. Leaf factor 3·7
(3) Colour of flower..	Bright yellow	White

	Gossypium herbaceum Dharwar No. I	*Gossypium neglectum rosea*
(4) Nectaries	Present	Absent
(5) Colour of lint	Dull white with reddish tinge	Pure white
(6) Ginning percentage of *kapas* ..	26 to 30 (mode 27 to 29)	30 to 40 (mode 35 to 38)
(7) Staple of lint	0·8 to 1·1 inch	0·4 to 0·7 inch

It is to the behaviour of the cross between these two types of cotton, in these contrasted characters, that the principal attention of the author has been directed.

IV. THE METHOD OF MAKING THE CROSS.

Cotton is normally a self-fertilized plant, but it is now proved that a certain limited amount of crossing does take place when different strains or varieties of cotton are grown in close proximity. This depends very largely on the number of insects present and particularly on the number of bees. At Dharwar the author's experiments would indicate that, with the strains with which he has worked, about two per cent. of natural crossing is normal, and this being the case, it is obvious that in all critical work the flowers must be protected from such natural crossing.

The method first adopted was to protect the flower buds with paper bags. This method has been frequently used in India and probably elsewhere. It has, however, been much criticised. Balls[1] objected to it in Egypt as it caused a great deal of shedding of flower buds and flowers. Leake[2] protected many thousands of flowers with paper bags, but found that his method led to a considerable degree of sterility. The author's experience of the methods under discussion was that the paper bags were very troublesome to use, and not very effective in a windy area, as they are liable to be torn and hence their value destroyed. The method has been abandoned in Madras, and a system of sewing up the flowers adopted in its place.[3] The author now only uses the paper bag method in protecting the flowers of the pollen parents and the buds operated upon in actual artificial crossing. In this case no satisfactory substitute has been found.

[1] *Cotton Plant in Egypt*, p. 117. [2] *Jour. Genetics*, Vol. I., p. 207.
[3] *Ann. Report. Dept. of Agri.*, Madras (1913).

In all other cases, where self-fertilization is desired, and hence complete protection from any chance of the admission of foreign pollen, the author has adopted a method of keeping the flowers closed by means of small wire rings.[1] The method was described in 1919, and has given satisfactory results, both before and since that time. The method is illustrated in the sketch below (Fig. 3) and consists of putting the small rings on to the fully developed

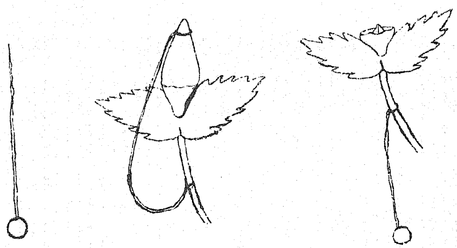

FIG. 3.

buds before they commence opening. The form of the flower being a cone, there is no difficulty in putting the rings tight, and so completely preventing the opening of the petals. The stalk of the protected flower is marked by a piece of cotton thread attached to the ring. In almost all cases, there is no further trouble. Occasionally, however, the ring slips off and the buds are thus allowed to open. All such flowers are removed, however, as soon as found.

The method thus described has been used with all the plants in which self-fertilization is essential, and all the results described in the present paper have been obtained with flowers so protected.

V. THE CHARACTERS OF THE HYBRID PLANTS.

The cross between the pure strains of *Gossypium herbaceum* and *Gossypium neglectum* var. *rosea* already described was made in December 1917, and twenty-two bolls were obtained which were sown separately in August 1918 (F_1). All gave plants and produce of one type, and it was evident that the cross had been successful in all cases. Among the plants grown, twelve were protected from cross-fertilization and self-fertilized and these yielded the

[1] *Agri. Jour., India,* Vol. XIV, p. 177.

material for the next generation's cultivation. The seed from each of these plants was grown separately, and it was at once obvious that much splitting of characters was taking place. Careful study of this was made, and the seed from plants of this generation (F_2) which showed any promise, and which were again protected from cross-fertilization, was again sown in 1920, the result being again carefully examined in the F_3 generation. A similar study was made of the F_4 generation sown in 1921. In the present chapter of this memoir, the author wishes to follow, through these four generations (F_1, F_2, F_3, F_4) of the cross, the behaviour of the characters already indicated.

(A) Colour of the cotyledonary stalk.

This character, which has of course only a scientific interest, was only followed through the F_1 and F_2 generations, as the climatic conditions in 1920-21 were unfavourable to obtaining correct results. Starting from the green stalk of Dharwar No. I and the deep red stalk of the *neglectum* parent (*rosea*), it was found that the F_1 generation gave a stalk which was *faint* red in every case. In the F_2 generation, there was a splitting of types resulting in coloured stalks as follows :—

Total number of plants examined	1,263
Deep red stalks	132
Faint red stalks	930
Green stalks	201

This gives a proportion between the different types of stalks of 1 : 7 : 1·5.

It is quite unsafe to suggest any reason for this proportion, on the basis of the two generations considered. It is obvious, however, that the colour is not a simple Mendelian character, involving the presence or absence of one colour factor.

(B) Shape of leaf.

The question as to the result of the cross between the two cotton types described in the matter of the shape of the leaf is of very great—though chiefly of theoretical—interest. The matter of how their character is inherited has already been discussed by Leake[1] on the basis of a cross between *Gossypium arboreum* and *Gossypium neglectum.* He has devised a co-efficient, which he terms the "leaf-factor," to represent the shape of the leaf. This leaf-factor is composed by subtracting the distance from the petiole to the sinus (l_1) from the length of the leaf from the petiole to the

[1] *Jour. Genetics*, Vol. I, No. 3, p. 224 (1911).

tip of the middle lobe (l), and dividing by the maximum breadth of the middle lobe (b). It is thus:

$$\frac{l-l_1}{b}$$

Though he finds that this factor varies somewhat with different leaves on the same plant, he considers that it is quite easy to select typical leaves, and his results for any plant are always based on the average figures given by two such leaves. A typical leaf was taken as being one which represented "the average of the factors of all leaves arising from the monopodial branches."[1]

He considers this factor as a single constant character, and that blending between the qualities represented by a long narrow-lobed leaf and a short broad-lobed leaf may occur in any proportion. A consideration of his results, however, does not definitely prove that the leaf-factor is really single inheritable quality, and some of them suggest that it may be a combination of two factors varying independently. The results which the author has obtained seem calculated to throw some light on the very obscure question of the inheritance of these leaf characters and they may therefore be discussed in some detail.

Instead of the "leaf-factor" as defined by Leake, the almost identical figure obtained by dividing the measurement of the length (l) and the breadth (b) of the middle lobe of the leaf has been used. This is simpler to obtain and varies so little from the figure given by Leake that it may be used without appreciable error. To exclude chance variations in a single plant, the measurements for each plant in a type were always made on either the fifth, sixth or seventh leaf arising on the main stem, when it was fully developed.

But while the leaf-factor has been used, the elements of which it is composed, the length and the breadth of the middle lobe have themselves been considered as possible hereditary characters, and their values in the parents and the offspring have been compared down to the F_4 generation. The difficulty in this case is that the absolute length and breadth of the middle lobe of the leaf are dependent not only on the innate hereditary characters of the plant itself, but also on the vigour with which the particular plant measured is growing. This difficulty is not altogether absent from the use of the leaf-factor itself, for when a plant is specially vigorous the middle lobe of the leaf increases in length faster in proportion to the increase in breadth.

This is clearly indicated by the following figures obtained from vigorous and non-vigorous plants of the same pure line of *Gossypium herbaceum* and also of *Gossypium neglectum* (*rosea*). (Fig. 4.)

[1] *Loc. cit.*, p. 229.

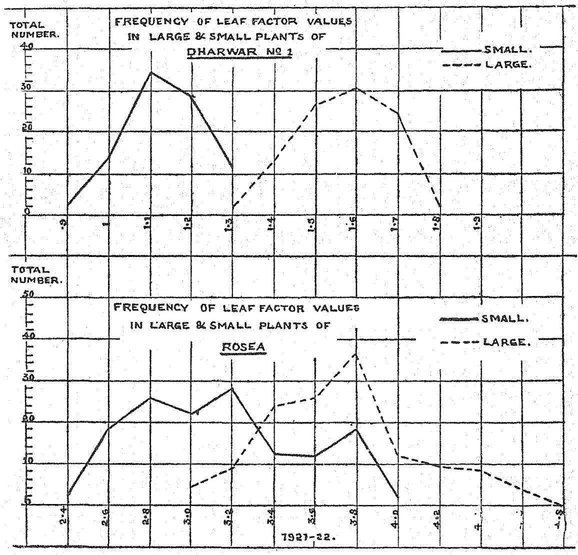

FIG. 4.

GOSSYPIUM HERBACEUM (DHARWAR No. I)

Leaf-factor and frequency.

(From 100 plants.)

Factor	Large plants	Small plants
0·9	..	2
1·0	..	16
1·1	..	38
1·2	..	31
1·3	2	13
1·4	13	..
1·5	27	..
1·6	32	..
1·7	24	..
1·8	2	..
	100	100

GOSSYPIUM NEGLECTUM (ROSEA)

Leaf-factor and frequency.

(From 138 plants.)

Factor	Large plants	Small plants
2·4–2·5	..	6
2·6–2·7	..	23
2·8–2·9	1	22
3·0–3·1	9	39
3·2–3·3	10	21
3·4–3·5	32	8
3·6–3·7	48	12
3·8–3·9	2	6
4·0–4·1	20	1
4·2–4·3	11	..
4·4–4·5	1	..
4·6–4·7	4	..
	138	138

So that it seems clear that the ratio which forms the leaf-factor itself is by no means constant, but tends to increase with the vigour of the plant.

Let us, however, first examine the constancy of the leaf-factor (1) on the same plant, (2) on plants of one pure strain. Leake states that this constancy with the strains he studied is very great, and that in the broad-lobed types (*i.e.*, those possessing a leaf-factor less than 2), the variation from the mean on one plant does not exceed 0·15 or a total range of 0·3. In the narrow-lobed types (*i.e.*, those with a leaf-factor greater than 3) the variation is greater, amounting to 0·3 from the mean, or a total range of 0·6[1]. The author's figures do not bear this out in every case. With the broad-lobed types, however, the constancy is fairly great, and the variation on one plant of Dharwar No. I has never exceeded 0·28, these figures being obtained from measurements of primary leaves from 500 plants. The range of variation obtained in different plants of the strain grown in one year is shown by the following measurements made on 508 plants, the leaves always used being the fifth, sixth, and seventh on the main stem.

Leaf-factor	Frequency	Per cent.
1·1–1·29	13	2·6
1·3–1·49	288	56·7
1·5–1·69	190	37·3
1·7–1·89	17	3·4

[1] *Loc. cit.*, p. 223.

The range between the extremes in this case among all plants of this strain is 0·7 or rather more than double what Leake found from his single plants of broad-lobed varieties.

When we consider the narrow-lobed varieties, the constancy of the leaf-factor, on which Leake lays great stress, no longer exists and the primary leaves *on a single plant* show themselves to be extremely variable. Thus in two single plants of the strain of *Gossypium neglectum* var. *rosea* used for the cross in 1920-21 the following variations were found, using only fully developed leaves on the main stem.

Leaf-factor.

Number of leaf (from base)	Plant No. I	Plant No. II
5th	3·1	3·1
6th	3·5	3·1
7th	3·5	3·0
8th	4·5	3·7
9th	3·9	3·9
10th	4·1	4·1
11th	4·4	4·0
12th	4·0	3·8
13th	3·9	4·0
14th	3·8	4·1
15th	3·8	4·3
16th	3·5	4·0
17th	3·5	3·8
18th	4·1	3·6
19th	4·0	3·8
20th	3·4	3·7
21st	3·5	3·1
22nd	4·1	3·2
23rd	4·1	3·6
24th	..	..
25th	..	..

Mode	3·5	3·1, 3·8, and 4·0
Mean	3·8	3·7
Range	1·4	1·3
Range as percentage of mean value.	36·8 per cent.	35·1 per cent.

It is obvious here that the variation on one and the same plant are of a totally different order from those indicated in Leake's figures. Though, if the measurements are limited to the leaves we have taken (5th, 6th, and 7th) for our general measurements, the range is much reduced, yet the fact that if we take say the 13th or the 15th leaf we should have got very wide difference from the finally recorded mean, rather tends to destroy our confidence in the factor itself. Leake[1] confesses that the leaf-factor is a purely empirical figure, and it became essential to find the reason for this very wide variation of mature primary leaves on a single plant.

Before indicating what this is we may, however, consider the figures obtained if we take not single plants but the strain as a whole. The factor was determined in fact on 594 plants of this strain growing at the same place at the same time (in 1920-21), the 5th, 6th, and 7th leaves being used in every case for measurement. The results are as follows :—

Leaf-factor	Frequency	Percentage
2·3–2·4	5	0·8
2·5–2·6	14	2·3
2·7–2·8	40	6·7
2·9–3·0	52	8·7
3·1–3·2	82	13·9
3·3–3·4	78	13·0
3·5–3·6	83	13·9
3·7–3·8	42	7·0
3·9–4 0	68	11·6
4·1–4·2	39	6·7
4·3–4·4	56	9 5
4·5–4·6	11	1·9
4·7–4·8	7	1·1
4·9–5·0	13	2·2
5·0–5·2	4	0·6

Mode .. .. 3·1 to 3·6
Mean .. .. 3·5
Range .. .. 2·8
Range as percentage of mean value 80·0 per cent.

Now, while the range in this case is higher than with a single plant, yet it is not more variable than would have been expected, having regard to the range of variations in leaves similarly placed on different single plants (see above 8th leaf 0·8, 15th leaf 0·5, 16th leaf 0·5), and it compels a further analysis into the cause of the variation. Is this variation due, in fact, (*a*) to variability in the type, (*b*) to variability in one of the elements which make up the

[1] *Loc. cit.*, p. 223.

leaf-factor, or (*c*) to variability in both of the elements which make up the leaf-factor ?

The variability cannot be due to more than a minor extent to that of the type, because (as shown above) the variation in a single plant is, though smaller, of the same order as that in the whole series of 596 plants. But let us consider the variation in the elements which make up the leaf-factor (*a*) in single plants, and (*b*) in the whole strain.

Taking the same plants as those for which the leaf-factor was given above we have for the mature leaves on the main stem from the 5th upwards as follows.

Length and breadth of middle leaf lobe.

Leaf number	Plant No. I		Plant No. II	
	Length of middle lobe	Breadth of middle lobe	Length of middle lobe	Breadth of middle lobe
	mm.	mm.	mm.	mm.
5th	75	24	75	24
6th	75	21	75	24
7th	78	27	90	30
8th	96	21	99	27
9th	93	24	105	27
10th	99	24	99	24
11th	105	24	96	24
12th	96	24	102	27
13th	93	24	96	24
14th	81	21	99	24
15th	81	21	90	21
16th	75	21	96	24
17th	75	21	81	21
18th	75	18	75	21
19th	72	18	81	21
20th	78	21	78	21
21st	75	21	75	24
22nd	75	18	78	24
23rd	..	..	75	21
Mode	75	21	75	24
Mean	82·9	21·3	87·6	23·9
Range	33	6	30	9
Range as percentage of mean	39·8 per cent.	28·2 per cent.	34·2 per cent.	37·7 per cent.

From this it would appear that the variation in each of these elements, the length and the breadth of the middle lobe, is about equal, in the same plant, to that of the leaf-factor itself. We may now see what is the case

with a whole population of 600 plants grown in the same year as the above. This has worked out as follows :—

Length of middle lobe	Frequency	Breadth of middle lobe	Frequency
mm.		mm.	
63	21	18	42
66	24	21	240
69	26	24	188
72	36	27	96
75	116	30	34
78	51	..	..
81	54	..	..
84	46	..	..
87	35	..	..
90	62	..	..
93	45	..	..
96	21	..	..
99	18	..	..
102	17	..	..
105	17	..	..
108	8	..	..
111	3	..	..
Mode ..	75 and 90		21
Mean ..	82·1		23·2
Range ..	48		12
Range as percentage of mean value	58·4 per cent.		57·7 per cent.

These figures show that while the range of variation of the leaf-factor in a single plant is practically as great as that of the actual measurements of length and breadth of the middle lobe of the leaf, its variability in a large population grown side by side in the same year is much greater (nearly double) than that of the actual measurements. This being the case, it would appear that the use of the leaf-factor tends to magnify the variability in this type of cotton and that considerably more constancy would be obtained by taking the actual measurements of specified leaves of plants grown side by side in the

same year, than by taking the combined co-efficient which Leake has termed the "leaf-factor."

In addition to this, it may be noted that though the co-efficient of variability of both the length and breadth is nearly the same, being 13·15 as regards the length (standard deviation 10·8 mm.) and 12·41 as regards the breadth (standard deviation 2·88 mm.), yet there is only very small correlation between the length and breadth. In other words, the length and breadth do not necessarily increase together, the co-efficient of correlation being only 0·28. This being the case, there seems strong reason for rejecting the leaf-factor, as a single unit, in the studies of the results of crossing, because

(1) The leaf-factor is more variable than the elements (length and breadth of the middle lobe) of which it is composed.

(2) The correlation between these elements is only slight.

We will, therefore, consider these elements as separate units, always providing (1) that the plants whose leaf characters are to be compared must be grown in the same year, at the same place, and at the same time, (2) that the leaves taken for measurement be always in a similar position on the plant. The author has always used the fifth, sixth or seventh leaf arising on the main stem as the basis for his measurements.

The characters of the middle lobe of the leaves, selected as just indicated, in the case of the parents of the cross, of the F_1 generation and of the F_2 generation, were determined on plants grown side by side in 1919-20 and the general results so far as the parents and the F_1 generation are concerned are graphically shown in Fig. 5. It will be seen from this that the length of the middle lobe in the two parents is as follows :—

Dharwar No. 1	37 to 54 mm.
Rosea	49 to 78 mm.

These figures hardly overlap. In fact, if we take a length of 51 millimeters as the line between them, only 4 out of 500 or 0.8 per cent. of the Dharwar No. I plants are above this line and only 3 out of 538 or 0·55 per cent. of the *rosea* type are below this line. In fact, we may take it that the range of variation in the two cases is separate, and that for practical purposes there is no overlapping of the types in this particular.

In the breadth of the middle lobe, the range of variation is, again, quite independent. The whole of the Dharwar No. I leaves have a breadth greater than 25 millimeters and the whole of the *rosea* leaves have a breadth less than 20 millimeters.

The behaviour in the F_1 generation is striking. All the plants obtained had figures for the dimensions of the middle lobe of the cross which indicated

a leaf of the type of *rosea* as to the length of the lobe, and of the type of Dharwar No. I as to the breadth of the lobe. This is shown by the following figures. (Fig. 5.)

BREADTH (m.m.)

LENGTH (m.m.)	13–15	16–18	19–21	22–24	25–27	28–30	31–33	34–36	37–39	40–42
37–39					6	13	DHARWAR 1			
40–42						58	44			
43–45					5	61	74	19		
46–48	ROSEA					31	81	69	5	4
49–51	3						11	6	5	4
52–54	5	9	10	1	5	1		2	1	1
55–57	25	13	6		F1	1				
58–60	20	48		1	3	2	5			
61–63	35	44			1					
64–66	35	90	20	7		8	6	5		
67–69	5	35	5			4	2			
70–72	16	58	13			6	5	1		
73–75		18	17		1	1	1			
76–78			8			1	3	6	2	2
79–81								1		
82–84						3		6	3	2
85–87									1	
88–90							2	1		

FIG. 5.

Name of cotton	Length of middle lobe	Breadth of middle lobe
	mm.	mm.
Dharwar No. I ..	37–54	25–42
Rosea	49–78	13–21
F_1	52–90	22–42

It will be noted, however, that in the F_1 generation the length tends, in the extreme cases, to be higher than any examples found among the parents. This tendency has already been noted by Leake.[1]

[1] *Loc. cit.*

From a consideration of these figures, tables, and curves, it would be natural to suspect practically complete dominance of the long leaf lobe over the short one, and of the broad leaf lobe over the narrow one, giving a leaf in the F_1 generation with a long-broad middle lobe. The actual characters of the leaf in the parents and in the F_1 generation are shown in Plate II.

Exactly what this apparent dominance means is elucidated by a study of the F_2 generation where 837 plants were grown and gave results shown in the following frequency tables, being worked out to a basis of 500 plants in each case.

Length of middle lobe.

Length	Dharwar No. 1	*Rosea*	F_1	F_2
mm.				
28–30	..	..	..	1
31–33	..	..	..	..
34–36	..	..	..	12
37–39	18	..	..	5
40–42	102	..	..	20
43–45	160	..	..	23
46–48	190	..	..	46
49–51	26	3	..	31
52–54	4	24	35	61
55–57	..	44	5	19
58–60	..	58	55	65
61–63	..	79	5	52
64–66	..	145	130	62
67–69	..	45	30	29
70–72	..	59	60	42
73–75	..	35	15	11
76–78	..	8	70	16
79–81	..	..	5	1
82–84	..	..	70	7
85–87	..	..	5	1
88–90	..	..	15	3
91–93	..	..	..	2
94–96	..	..	..	1

Breadth of middle lobe.

Breadth	Dharwar No. I	*Rosea*	F_1	F_2
mm.				
10–12	..	..	..	2
13–15	..	134	..	26
16–18	..	287	..	51
19–21	..	79	..	55
22–24	..	..	45	104
25–27	11	..	50	116
28–30	163	..	135	68
31–33	210	..	120	41
34–36	96	..	100	26
37–39	11	..	30	9
40–42	9	..	20	1
43-45	..	..	..	1

Taking the question of lobe *length* first, and taking a length of 51 mm. as separating long lobes from short ones, it is found that in the F_1 generation all the plants have leaves which would be classed as long* and in the F_2 generation the proportion is as follows (out of 837 plants).

	Total	Proportion
Long-lobed leaves	605	2·61
Short-lobed leaves	232	1

The proportion, in fact, approaches what one would expect to get with a single pair of hereditary characters.

With the leaf breadth the position is similar. A width of 21 mm. may be taken to divide narrow from wide leaves, as *all* the *narrow* types are below this limit, and all the broad types above it. In the F_1 generation all the plants have leaves conforming to this definition of a broad-lobed leaf, and in the F_2 generation the figures are as follows (out of 837 plants).

	Total	Proportion
Broad-lobed leaves	611	2·7
Narrow-lobed leaves	226	1

The result is, in fact, exactly similar to that obtained above in studying the length of the lobe, that is to say, the proportion is very nearly what would be expected with a simple pair of hereditary characters.

If these two lobe characters are studied together, and they are considered as two pairs of hereditary characters, varying independently, we get the following results in the F_2 generation out of 837 plants.

Characters of leaf lobe	Total	Proportion
Long broad	431	8·3
Long narrow ..	174	3·3
Short broad ..	180	3·4
Short narrow ..	52	1

This is very nearly the proportion which would be expected (9 : 3 : 3 : 1) if two simple characters were varying independently, and it was clear that a study of the next generation of plants (F_3) would confirm or otherwise the truth of this deduction.

The study of the third generation (F_3) was made in 1920-21, and as the plants were now grown in a new year it became necessary to remeasure the length and breadth of the lobes of parents, F_1 and F_2, along with the F_3 generation, in order to see whether, under the conditions of the new season, the

* This is justified, as all one parent (except 0.8 per cent.) are below this limit and all the other parent (except 0.6 per cent.) are above it. It is in no sense an artificial point.

same standards of length and breadth could be taken as before. The results obtained were as follows :—

Length of middle lobe.

Length	Dharwar No. I	*Rosea*	F_1
mm.			
28–30	8	..	..
31–33	10	..	..
34–36	24	..	..
37–39	26	..	..
40–42	28	..	..
43–45	42	..	..
46–48	50	..	..
49–51	98	..	..
52–54	61	1	..
55–57	56	..	..
58–60	49	..	..
61–63	33	2	..
64–66	15	4	..
67–69	..	4	..
70–72	..	16	..
73–75	..	42	..
76–78	..	32	..
79–81	..	37	4
82–84	..	46	7
85–87	..	50	12
88–90	..	78	35
91–93	..	55	79
94–96	..	43	120
97–99	..	28	74
100–102..	..	19	48
103–105..	..	21	34
106–108..	..	5	12
109–111..	..	4	35
112–114..	..	6	14
115–117..	..	2	8
118–120..	..	7	13
121–123..	..	..	5

Breadth of middle lobe.

Breadth	Dharwar No. I	*Rosea*	F_1
mm.			
16–18..	..	47	..
19–21..	..	152	..
22–24..	..	191	..
25–27..	..	82	..
28–30..	4	28	..
31–33..	62	..	..
34–36..	76	..	31
37–39..	141	..	97
40–42..	123	..	131
43–45..	52	..	128
46–48..	36	..	91
49–51..	6	..	22

The first thing to be noticed about these figures is the extreme importance and even necessity of growing all plants which are to be compared in the same year. The conclusions which were reached for a consideration of the 1919-20 figures are equally true here, but the leaves here are longer and broader, or, in other words, bigger than in the previous year. The length of the middle lobe of the two parents was—

Dharwar No. I	28 to 66 mm.
Rosea	61 to 120 mm.

These figures again hardly overlap. In fact if we take a length of 66 mm. as the line between the short and long leaves, no plants of the Dharwar No. I parent will be above this line, and only 6 out of 500 plants or 1·2 per cent. of the *rosea* parent are below it. The range of variation in the two cases is practically separate. The breadth of the middle lobe gives similar results. The range was as follows :—

Dharwar No. I	28 to 51 mm.
Rosea	15 to 30 mm.

Here we can take 30 mm. breadth as the dividing line, and if we do so, then only 4 plants (or 0·8 per cent.) of the Dharwar No. I parent overlap the range of the other type, while none of the *rosea* parent overlaps at all.

In the F_1 generation the results are similar to those recorded in the previous year. Both long leaf lobes and broad leaf lobes again appear as simple dominants and the conclusions already drawn (page 93) seem to be confirmed. The interest of the culture in 1920-21 lay, however, in the characters of the F_3 generation. For this the whole of the seed obtained from a certain number of each type of plant in the F_2 generation was used. The number so used was as follows :—

(*a*) Seed from thirteen plants with long broad-lobed leaves.
(*b*) Seed from seven plants with long narrow-lobed leaves.
(*c*) Seed from five plants with short broad-lobed leaves.
(*d*) Seed from one plant with short narrow-lobed leaves.

The results of growing these are shown in the following series.

(*a*) *From thirteen plants with long broad-lobed leaves.*

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	92	66	26	..	..	2·5	1·0	..	..
2 ..	102	76	26	..	..	2·9	1·0	..	..
3 ..	95	52	21	16	6	10·4	4·2	3·2	1·0
4 ..	71	39	16	11	5	8·0	3·2	2·2	1·0
5 ..	76	55	1	18	2	3·0	..	1·0	..
6 ..	93	93	..	..	..	1·0	..	..	..
7 ..	100	58	14	22	6	9·6	2·3	3·6	..
8 ..	60	32	14	11	3	10·6	4·6	3·3	1·0
9 ..	101	100	..	1	..	1·0	..	..	..
10 ..	83	61	20	2	..	3·0	1·0	..	..
11 ..	111	82	29	..	..	2·8	1·0	..	..
12 ..	118	86	3	29	..	3·0	..	1·0	..
13 ..	83	82	1	..	..	1·0	..	..	..

In this case, therefore, out of thirteen plants grown,

(*a*) three were pure long broad-lobed leaf types ;

(*b*) four were pure long-lobed types, but contained elements of both broadness and shortness. There is, on the average, a proportion of long broad-lobed types to long narrow-lobed types of 2·8 : 1. The proportion expected with one pair of varying characters would be 3 : 1 ;

(*c*) two were pure broad-lobed types, but contained elements of both length and shortness. There is, on the average, a proportion of long broad-lobed types to short broad-lobed types of 3 : 1. This is exactly what would be anticipated ;

(*d*) four contained elements of both length and shortness, and of breadth and narrowness. There is on the average a proportion of long-broad, long-narrow, short-broad, and short-narrow of 9·6 : 3·2 ; 3·0 : 1.

The behaviour of the plants which had long and broad-lobed leaves in the F_2 generation was almost exactly what would have been expected on the hypothesis of two independently varying hereditary pairs of characters.

(b) From seven plants with long narrow-lobed leaves.

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	64	..	64	..	..	..	1·0	..	..
2 ..	88	..	69	..	19	..	3·6	..	1·0
3 ..	82	1	81	..	..	..	1·0	..	..
4 ..	87	3	60	..	24	..	2·5	..	1·0
5 ..	96	1	92	..	3	..	1·0	..	..
6 ..	82	1	80	..	1	..	1·0	..	..
7 ..	83	1	80	..	2	..	1·0	..	..

In this case, therefore, out of seven plants grown, five were, to all intents, pure long narrow-lobed types. The other two were pure narrow-lobed types, but contained elements of both length and shortness. There is, on the average, a proportion of long narrow-lobed to short narrow-lobed types of 3·1 : 1. This is almost exactly what would have been anticipated on the supposition of two independently varying hereditary pairs of qualities.

(c) From five plants with short broad-lobed leaves.

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	104	1	..	75	28	..	..	2·7	1·0
2 ..	95	1	..	63	31	..	..	2·0	1·0
3 ..	84	1	..	81	2	..	..	1·0	..
4 ..	47	..	..	46	1	..	..	1·0	..
5 ..	92	2	1	89	..	..	..	1·0	..

In this case, therefore, out of five plants grown, three were, to all intents and purposes, pure short and broad-lobed types. The other two were pure short-lobed types, but contained elements of both breadth and narrowness. There is, on the average, a proportion of short broad-lobed to short narrow-lobed types of 2·3 : 1. This is not quite the proportion expected (3 : 1) but considering the small number of plants investigated, it is not much further from it than perhaps might have been anticipated.

(*d*) *From one plant with short narrow-lobed leaves.*

Seed from only one carefully selected plant of this type was secured, and gave 77 plants of the F_3 generation. These gave on growing :—

Long broad-lobed leaves	..	None
Long narrow-lobed leaves	..	1
Short broad-lobed leaves	..	1
Short narrow-lobed leaves	..	75

This was, as would have been expected, from a pure recessive type.

The F_4 generation, which has been taken in 1921-22, enables us to go a stage further in this discussion.

Seed obtained from the following plants were used for cultivation.

I. *Long broad-lobed plants.*

(*a*) Seed from 13 plants of the F_3 generation, the history of whose parentage is as follows :—

F_1. *Long broad*-lobed leaves.

F_2. *Long broad*-lobed leaves.

F_3. All *long broad*-lobed leaves.

(*b*) Seed from 8 plants of the F_3 generation, the history of whose parentage is as follows :—

F_1. *Long broad*-lobed leaves.

F_2. *Long broad*-lobed leaves.

F_3. All variations found, but *long broad*-lobed leaves selected for producing the seed in the present case.

(*c*) Seed from 7 plants of the F_3 generation, the history of whose parentage is as follows :—

F_1. *Long broad*-lobed leaves.

F_2. *Long broad*-lobed leaves.

F_3. Only long broad and short broad-lobed leaves found but *long broad*-lobed leaves selected for producing the seed in the present case.

The results of growing the seed were as follows :—

(a) From thirteen plants with pure long broad-lobed leaves.

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	66	66	..	..	..	1·0	..	..	..
2 ..	94	91	..	3	..	0·97	..	0·03	..
3 ..	81	79	..	2	..	0·97	..	0·03	..
4 ..	77	77	..	..	..	1·0	..	..	..
5 ..	94	93	..	1	..	0·99	..	0·01	..
6 ..	118	118	..	..	..	1·0	..	..	..
7 ..	95	94	..	1	..	0·99	..	0·01	..
8 ..	90	90	..	..	..	1·0	..	..	..
9 ..	103	103	..	..	..	1·0	..	..	..
10 ..	89	89	..	..	..	1·0	..	..	..
11 ..	71	68	3	..	..	0·96	0·04	..	..
12 ..	103	98	2	3	..	0·95	0·02	0·03	..
13 ..	75	66	3	6	..	0·88	0·04	0·08	..

The plants are therefore substantially pure types with a long broad-lobed leaf, and breed pure. Plant No. 13 seems a little aberrant, but it has not been possible so far to follow this up.

(b) From eight plants from a family in the F_3 generation which contains all four varieties in leaf shape.

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	129	74	22	26	7	10·5	3·1	3·7	1·0
2 ..	114	65	18	24	7	9·2	2·6	3·4	1·0
3 ..	135	93	..	42	..	3·1	..	1·0	..
4 ..	103	..	103	..	..	..	1·0	..	..
5 ..	74	41	10	19	4	10·2	2·5	4·1	1·0
6 ..	103	..	..	103	..	..	..	1·0	..
7 ..	109	43	26	34	6	7·1	4·3	5·6	1·0
8 ..	83	35	21	22	5	7·0	4·2	4·5	1·0

In this case it is obvious that Nos. 1, 2, 5, 7, and 8 still contain elements of all four possible varieties, and the proportion of these is as follows, taken together :—

L. B. : L. N. : S. B. : S. N. :: 8·9 : 3·4 : 4·3 : 1.

This is not the exact Mendelian ratio to be expected, but is very close to it. In No. 3 the parent appears to contain the "broad" character exclusively as no narrow-leaved plants are found among the progeny, but it has elements of "length" and "shortness" as previously defined, and the proportion of "long-broad" to "short-broad" lobed leaves is again almost exactly what would be expected in dealing with a simple Mendelian factor. In the case of Nos. 4 and 6, the parent appears to be pure as to leaf character, as all the progeny in the former case have long narrow-lobed leaves and in the latter short broad-lobed leaves.

(*c*) *From seven plants from a family in the F_3 generation, which contains "long-broad" and "short-broad" elements.*

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	101	1	..	100	..	..	..	1·0	..
2 ..	107	82	..	25	..	3·2	..	1·0	..
3 ..	91	..	..	91	..	..	..	1·0	..
4 ..	86	66	..	20	..	3·3	..	1·0	..
5 ..	101	..	..	101	..	..	..	1·0	..
6 ..	93	70	..	23	..	3·0	..	1·0	..
7 ..	111	5	..	106	..	0·04	..	0·96	..

In the results of this generation we get, therefore, a total absence of narrow leaves as we should expect. Three plants out of the seven have given a progeny with both "long-broad" and "short-broad" lobed leaves in the following proportion :—

L.B. : S.B. :: 3·3 : 1.

This is again almost the expected ratio for two simple Mendelian factors. The remaining plants have produced progeny with almost only short broad-lobed leaves. The only exceptions are five plants out of 111 in No. 7 above, whose history can be followed up in the next generation and a possible explanation found. The whole of these five apparently aberrant plants are only very slightly over the boundary of 'shortness', four being four per cent. above and the fifth being nine per cent. above.

II. *Long narrow-lobed plants.*

In this case seed was taken from six plants of the F_3 generation derived from parents in the F_2 generation which only produced progeny with *long*

narrow-lobed leaves. These were cultivated in order to see whether the apparent purity in the F_3 generation was maintained in the F_4 generation.

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	96	..	94	..	2	..	..	..	..
2 ..	75	..	75	..	..	..	..	..	..
3 ..	74	..	71	..	3	..	1	..	..
4 ..	91	2	88	..	1	..	..	..	..
5 ..	99	..	98	..	1	..	..	..	..
6 ..	58	..	58	..	..	..	..	..	..

It is evident therefore that the purity of the strain is maintained, the few aberrant forms being only slightly over or under the selected boundary of shortness respectively. Thus of the three plants marked as 'long-broad' the actual breadth measurements were as follows :—

(*a*) Limit of breadth for narrow leaves .. .. 30 mm.
(Plant 1) 0·1 .. .. 33 „
(Plant 4) { 0·2 .. .. 33 „
0·3 .. .. 33 „
(*b*) Limit of length for short leaves .. .. .. 66 „
(Plant 1) { 0·1 .. .. 63 „
0·2 .. .. 60 „
(Plant 3) { 0·3 .. .. 63 „
0·4 .. .. 63 „
0·5 .. .. 63 „
(Plant 4) 0·6 .. .. 60 „
(Plant 5) 0·7 .. .. 63 „

III. *Short narrow-lobed plants.*

In this case seed was taken from two plants of the F_3 generation. These were derived from plants in the F_2 generation which only gave progeny with short narrow-lobed leaves. It formed, in fact, a test of the real purity or otherwise of the apparently pure recessive type in the F_3 generation by growing the whole of progeny.

No.	No. of plants	Plants with lobes				Proportion			
		Long broad	Long narrow	Short broad	Short narrow	Long broad	Long narrow	Short broad	Short narrow
1 ..	69	..	..	..	69	..	..	..	1
2 ..	93	..	..	1	92				

The one plant which ranks as short broad was only 33 mm. broad, the limit for narrow leaves being 30 mm. It hardly, therefore, exceeded the limit, and the whole of the progeny of the two test plants remained pure, as would be the case if we are dealing with a pair of recessive characters.

The conclusions obtained from a consideration of the F_4 generation, therefore, substantially confirm those reached in the previous year.

In summary, regarding the shape of the leaf considered as a hereditary character in the cross between the strains of *Gossypium herbaceum* and *Gossypium neglectum* described above, it may be stated—

(1) That the "leaf-factor" introduced by Leake as a single figure to represent the shape of the leaf would seem to be complex, as variability of the length and breadth of the middle lobe is greater than that of its factors, and the correlation between these latter is only slight, the co-efficient of correlation being only 0·28.

(2) That, provided the plants are grown under the same conditions, in the same year, and that similarly placed leaves are taken for the measurements, the length and the breadth of the middle lobe of the leaf are single hereditary characters varying independently.

(3) That the broad-lobed leaf of the Dharwar No. I parent is dominant over the narrow-lobed leaf of the *rosea* parent and the long-lobed leaf of *rosea* is dominant over the short-lobed leaf of Dharwar No. I. The F_1 generation consists therefore entirely of long broad-lobed leaves, the range of length extending, however, beyond the longest leaf of the *rosea* parent.

(4) That in the F_2 generation the splitting of the cross occurs in almost the Mendelian ratio for two independently varying characters, namely:—

Long broad-lobed leaves	..	8·3
Long narrow-lobed leaves	..	3·3
Short broad-lobed leaves	..	3·4
Short narrow-lobed leaves	..	1·0

(5) That in the F_3 and F_4 generations the splitting of the cross continues and the descendants of the various types of plant in the F_2 generation again almost exactly correspond with what would occur with two independently varying Mendelian characters. The variation from the theoretical figures are not large, but later on it is hoped to investigate the reason for them.

(C) Colour of flower.

The previous work on the colour of the flower as a hereditary character has been referred to in Chapter I. Fletcher found that in crosses between yellow flowers and white flowers the former proved a dominant character, a

conclusion which was verified by Fyson. Balls, on the other hand, found that the inheritance of colour of flower was complex, but he was not able to elucidate its character completely. Leake again very closely investigated the matter on the basis of the crosses he made between strains of *Gossypium arboreum* (*narma*) and *Gossypium neglectum.* He distinguishes between two kinds of yellow colour, a full yellow and what he terms "pale yellow." He states [1]: "The yellow colour is dependent on a colour producing factor, which, according to its presence or absence, gives rise to a simple pair of allelomorphic characters, of which the presence of the colour producing factor is dominant in both cases. That is, the yellow is dominant both to pale yellow and to white." He adds: "In the present, therefore, it is impossible to say what relations exist between the two conditions which may be indicated by the presence and absence of the pale yellow factor. . . . It is clear, however, that this condition does not correspond with that denoted by Balls as lemon yellow, which he found to represent the impure stage in the cross between full yellow and white flowered parent in the Egyptian cottons." Since the publication of the memoir by Leake and Ram Prasad from which these extracts are made, there appear to have been no further publications on the subject.

The author's cross was between a full yellow-flowered type (Dharwar No. I) and a pure white-flowered type (*rosea*), and the resulting crosses have given very interesting results, which may now be detailed.

(1) In the F_1 generation the whole of the plants obtained gave pale yellow flowers. The actual difference in colour between the parents and the F_1 generation is shown by the following analysis of the colours on Lovibond tintometer.

Frequency distribution of colour.

Lovibond's degrees (Yellow)	Dharwar No. I	*Rosea*	F_1 generation
5·0	..	..	1
5·25	..	..	20
5·5	..	..	49
5·75	..	..	30
6·0	..	..	..
6·25	..	..	..
6·5	4	..	..
6·75	21	..	..
7·0	45	..	..
7·25	26	..	..
7·5	4	..	..

[1] Leake and Ram Prasad. Studies in Indian Cottons. *Mem. Dept., Agri. India, Bot. Ser.*, Vol. VI, No. 4, page 126 (1914).

(2) In the F_2 generation out of a total of 1,057 plants, the colours were as follows :—

	No. of plants	Proportion
Pale yellow	643	3·9
Full yellow	162	1·0
White	252	1·6

There was no difficulty in distinguishing these colours in the morning soon after they opened. If the examination was delayed until the late afternoon, a certain amount of fading of the yellow colour had occurred, and it was not so easy to distinguish the colours. Hence all examinations were made in the morning soon after the flowers opened.

It is obvious that the colour of the flower is not a single Mendelian factor in which the pair is (1) colour and (2) absence of colour, but it is difficult, on the basis of the characters in the F_2 generation only, to understand clearly how the actual colours found are composed. The F_3 generation gives, however, some light on this point.

(3) For the F_3 generation seed from 32 plants of the F_2 generation was planted. Of these—

17 plants were pale yellow in the F_2 generation.
10 plants were full yellow „ „ „
5 plants were white. „ „ „

Let us consider the way in which these behave.

(*a*) All the plants which had white flowers in the F_2 generation also yielded white flowers in the F_3 generation as follows :—

Serial No.	Total number of plants	Pale yellow	Full yellow	White
1	68	nil	nil	68
2	74	nil	nil	74
3	81	nil	nil	81
4	43	nil	nil	43
5	102	nil	nil	102

(*b*) All plants which had *full yellow* flowers in the F_2 generation gave flowers of varying colours in the F_3 generation as follows :—

Serial No.	Total number of plants	Pale yellow	Full yellow	White	Proportion		
					Pale yellow	Full yellow	White
1 ..	71	..	71	..	0	1·0	0
2 ..	67	..	67	..	0	1·0	0
3 ..	58	..	58	..	0	1·0	0
4 ..	63	16	47	..	1	2·9	0
5 ..	57	12	45	..	1	3·7	0
6 ..	73	24	49	..	1	2·0	0
7 ..	72	21	51	..	1	2·4	0
8 ..	73	16	57	..	1	3·6	0
9 ..	58	0	42	16	0	2·6	1
10 ..	68	0	49	19	0	2·5	1

(*c*) The plants which had *pale yellow* flowers in the F_2 generation gave flowers of varying colour in the F_3 generation as follows :—

Serial No.	Total number of plants	Pale yellow	Full yellow	White	Proportion		
					Pale yellow	Full yellow	White
1 ..	68	68	..	..	1·0	0	0
2 ..	68	66	2	..	1·0	0	0
3 ..	61	49	0	12	4·0	0	1
4 ..	74	58	0	16	3·6	0	1
5 ..	69	51	0	18	2·8	0	1
6 ..	75	60	0	15	4·0	0	1
7 ..	81	59	0	22	2·7	0	1
8 ..	66	48	18	..	2·6	1	0
9 ..	75	54	21	..	2·5	1	0
10 ..	76	64	12	..	5·3	1	0
11 ..	63	46	17	..	2·7	1	0
12 ..	75	51	24	..	2·1	1	0
13 ..	66	46	20	..	2·3	1	0
14 ..	79	45	11	23	4·0	1	2·0
15 ..	78	48	12	18	4·1	1	1·5
16 ..	61	34	10	17	3·4	1	1·7
17 ..	59	32	9	18	3·6	1	2 0

It is obvious, therefore, that the white colour is a pure recessive character in the crossing of these two types, as the whole of those plants which had white flowers in the F_2 generation bred true in this character. The constitution of the yellow-flowered plants was, however, more complicated and it could not

be pretended that the constitution of the colour of these flowers had been completely deciphered. The matter was, therefore, further examined in the F_4 generation.

(4) For the F_4 generation seed from 34 plants of the F_3 generation was planted. Of these—

12 plants were pure white in F_2 and F_3 generations.

13 plants were full yellow in F_2 and F_3 generations.

9 plants were pale yellow in F_2 and F_3 generations.

These behaved as follows :—

(*a*) All the plants which had white flowers in the F_2 and F_3 generations also yielded white flowers in the F_4 generation.

Serial No.	Total number of plants	Pale yellow	Full yellow	White
1 ..	53	..	..	53
2 ..	82	..	..	82
3 ..	49	..	..	49
4 ..	63	..	..	63
5 ..	71	..	..	71
6 ..	47	..	..	47
7 ..	101	..	..	101
8 ..	94	..	..	94
9 ..	82	..	..	82
10 ..	78	..	..	78
11 ..	63	..	..	63
12 ..	82	..	..	82
	865			865

(*b*) The plants which had *full yellow* flowers in the F_2 and F_3 generations gave flowers of varying colours in the F_4 generation as follows :—

Serial No.	Total number of plants	Number of plants with colours			Proportion		
		Pale yellow	Full yellow	White	Pale yellow	Full yellow	White
1 ..	85	..	85	..	..	1	..
2 ..	101	..	101	..	..	1	..
3 ..	93	..	93	..	..	1	..
4 ..	114	..	114	..	..	1	..
5 ..	72	..	72	..	..	1	..
6 ..	81	..	81	..	..	1	..
7 ..	110	..	110	..	..	1	..
8 ..	120	..	120	..	..	1	..
9 ..	116	15	101	..	1	6·7	..
10 ..	82	24	44	14	1·7	3·1	1
11 ..	69	8	54	7	1·1	7·7	1
12 ..	68	3	62	3	1	20·6	1
13 ..	58	5	50	3	1·6	16·6	1

Now all the plants (Nos. 1—8), which yielded full yellow-flowered progeny only, were derived from plants of the F_2 generation which likewise yielded full yellow-flowered progeny only. So that in these eight cases there is a record of full yellow-flowered plants only for three generations, and hence this colour seems to be hereditary as a single character, which may, however, be simple or compound.

The remainder of the plants, derived from F_2 plants with full yellow flowers which yielded both pale and full yellow-flowered progeny in the F_3 generation, all gave descendants varying in this character. In one case (No. 9) only pale yellow and full yellow progeny were produced in the previous generation, though the proportion of full yellow plants is now much higher as follows :—

	Pale yellow	Full yellow
F_3	1	3·7
F_4	1	6·7

In the remaining cases all three types of colour appeared in the progeny but in very different proportion, so different in fact that it is difficult to believe that we are dealing with simple colour characters at all.

(*c*) The plants which had *pale yellow* flowers in the F_2 and F_3 generations gave flowers of varying colours in the F_4 generation as follows :—

Serial No.	Total number of plants	Number of plants with colours			Proportion		
		Pale yellow	Full yellow	White	Pale yellow	Full yellow	White
1 ..	136	104	..	32	3·2	..	1·0
2 ..	80	56	..	24	2·4	..	1·0
3 ..	98	73	8	17	9·1	1·0	2·1
4 ..	93	59	12	22	4·9	1·0	1·8
5 ..	72	43	5	24	8·6	1·0	4·8
6 ..	104	57	47	..	1·2	1·0	..
7 ..	143	118	25	..	4·5	1·0	..
8 ..	102	45	36	21	2·1	1·7	1·0
9 ..	113	73	17	23	4·3	1·0	1·5

These figures show an extraordinary complexity in the colour character of the pale yellow flowers. It may be of interest to examine the parentage

from the F_2 generation of these plants. For this purpose there are four groups as follows :—

Nos. 1 *and* 2.

F_2 Pale yellow plants, gave in.
F_3 Pale yellow plants only.
F_4 Pale yellow and white plants in proportion of *2·8* pale yellow to *1* white.

Nos. 3, 4 *and* 5.

F_2 Pale yellow plants, gave in.
F_3 Pale yellow and white plants, in proportion of *4·0* pale yellow to *1* white.
F_4 Plants of all three colours in proportions varying in each case.

Nos. 6 *and* 7.

F_2 Pale yellow plants, gave in.
F_3 Pale yellow and full yellow plants in proportion of *2·6* pale yellow to *1* full yellow.
F_4 Pale yellow and full yellow plants only but in widely different proportions.

Nos. 8 *and* 9.

F_2 Pale yellow plants, gave in.
F_3 Pale yellow, full yellow and white plants in proportion of *4* pale yellow to *1* full yellow and *2* white.
F_4 Pale yellow, full yellow and white plants in widely different proportions in the two cases.

It is obvious, therefore, that we are in face of a much more complex character in the colour of the flowers of the cotton plant than has hitherto been thought, and the studies made so far will have to be extended considerably before it will be possible to elucidate the question. Two or three points are, however, clear. Thus it seems proved that the pale yellow colour of the flowers of some plants is not in any sense a mere blending of the full yellow colour of one of the parents into the white of the other. The three colours have, in fact, distinct characters of their own. All white-flowered plants will breed true in colour of flower. Some of the full yellow plants will do so, but others will give progeny with both pale yellow and full yellow flowers or with flowers of all three colours. The full yellow colour can, however, be fixed as a hereditary character. Plants with pale yellow flowers have never bred true in this colour character, and the progeny may be a mixture of pale yellow and white, of pale yellow and full yellow, or of all three colours in widely differing proportions.

Beyond this little can be said, and it will need a good deal more study than the author has yet been able to make, taking account of the various tints involved, before the very complicated inheritance of the colour character of the flower of the cotton plant can be clearly made out.

(D) Length of the flower petal.

There appear to be two types of petal among species of the genus *Gossypium*, one of which is so small that the petal is usually completely enclosed by the bracteole and the other where the petal is so large as to go far beyond it. And this relationship to the bracteoles is considered by Leake[1] to be a sufficient definition of the size of the petal in any particular case. He considers that the two types of petal "stand in marked contrast, without intermediate form." This being the case, he noted the close linkage of the size of petal and the colour, small petals being always white and yellow petals being invariably large. The author is not aware of any other work which has been done on the question of the inheritance of the size of petal in cotton plants.

It was necessary in the author's experiments first to have a more rigid definition of the size of the large and small petals. This is necessary because the bracteoles themselves vary very widely in size, and what would be called a small petal may extend beyond the length of a small bracteole and *vice versâ*. In the present work, therefore, a large petal has been defined as one more than 22 mm. in length, and a small petal as one below this limit. This is a fairly satisfactory classification though it will be noted that there is slight overlapping of the sizes in the two parents. The author, in fact, cannot confirm the statement of Leake that there are two essentially different types of petal and none of intermediate size.

The length of the petals of the two parents in the present case and also of the first generation of the cross is shown in the following table indicating the frequency of petals of different sizes in each case. The table is based on the examination of flowers from 500 plants in each case.

Length of petal.

Length	Dharwar No. I	*Rosea*	F_1
mm.			
10–12 ..	..	12	..
13–15 ..	..	22	..
16–18 ..	..	170	..
19–21 ..	9	255	21
22–24 ..	66	41	94
25–27 ..	144	..	213
28–30 ..	225	..	160
31–33 ..	51	..	12
34–36 ..	4	..	..
37–39 ..	1	..	..

[1] *Jour. Genetics*, Vol. I, No. 3 (1911), p. 242.

In the Dharwar No. I parent, 1·8 per cent. of the total plants are below the line empirically fixed as that of separation between large and short petals. In the case of the *rosea* parent, 8·3 per cent. are above this line, and in the case of the cross (F_1), while the large petal is evidently a dominant character, 4·2 per cent. of the plants give flowers with petals below 22 mm. in length.

In the F_2 generation several points were noted.

(1) As would be expected from Leake's experience, the correlation between white flowers and short petals was almost, though not quite, complete. In fact, out of 252 white-flowered plants, 243 gave flowers with short petals and 9 with large petals. It is curious and very suggestive that the correlation in the cases here studied was not so complete as in those examined by Leake.

(2) The splitting of the types in the F_2 generation was very curious, and so far an explanation has not been found which will account for it. The following table shows, side by side, the frequency of the various lengths of petal in the F_1 and F_2 generations.

Length of petal.

Length	F_1	F_2 Total	F_2 White flower	F_2 Yellow flower
mm.				
10–12	..	6	5	1
13–15	..	82	63	19
16–18	..	149	60	89
19–21	21	133	16	117
22–24	94	103	3	100
25–27	213	23	1	22
28–30	160	4	0	4
31–33	12	..	..	..
34–36	..	..	..	..
37–39	..	..	..	..

The result in the F_2 generation, as already stated, seems unaccountable. Instead of the dominant large petal giving the largest proportion of large petals in this generation, only 228 plants had large petals and 643 had short petals, or a proportion of 1 to 2·8, being nearly the reverse of what had been expected.

One of the reasons by which this strange phenomenon can be explained is to be found in the fact of the high degree of correlation between the white colour of the flower and the short length of petal noted above. If, however, this were the only cause of the disturbance of the usual ratio, the expected proportion would be obtained with plants bearing flowers of other colours. But the number of large and short-petalled plants among those bearing yellow flowers (including full yellow and pale yellow) was as follows :—

Large petals	184
Short petals	316

The proportion between the large-petalled plants and the short-petalled plants is 1 to 1·71, which on the basis of present knowledge is quite unaccountable. The matter has not yet been investigated in the F_3 or F_4 generations, but this will be taken up as soon as time allows, as the problem which it opens out seems of exceeding interest.

(E) Presence of nectaries.

The presence of both foliar and extra floral nectaries is characteristic of *Gossypium herbaceum*, while in the case of *Gossypium neglectum* these organs are sometimes present, but sometimes completely wanting. No note appears to have been made by previous writers as to the behaviour of this feature of certain cotton varieties on crossing, and as the type of *Gossypium neglectum* used in these experiments had been totally without the glands in question for several generations, the behaviour on crossing seemed worthy of careful record.

On the cross between Dharwar No. I and *rosea* being made, it was found that the plants of the F_1 generation possessed both extra floral and foliar glands, so that the presumption is that this character is a normal Mendelian dominant.

In the F_2 generation, 1,050 plants were examined with the following results :—

Number with glands (nectaries)	743
Number without glands	307

The proportion is 2·4 to 1. This is not quite the proportion expected, and it would appear that we are not in the presence of a completely simple character. The investigation has not yet been carried further, but it may be possible to do this in the near future.

(F) Ginning percentage.

The ginning percentage of the *kapas* is one of the most important characters of a type of cotton, and as before stated, the primary purpose for which the present cross was made was to combine the high ginning character of the *neglectum* cottons with the good staple of the *kumpta* type of *Gossypium herbaceum*.

How far the proportion of lint to seed is a hereditary character is not clear from the published record of work done on cotton breeding. The only worker on the subject who has dealt with this question is Balls,[1] and he has only considered the distribution of the lint on the seed. He finds that a regular distribution of the lint is dominant over an irregular distribution, but as regards the *amount* of lint he offers no experiments and makes no statement. The matter is, however, in the present case, of vital importance to the utility of any plants from the resulting cross.

The ginning percentage of the seeds from 100 plants of the *Gossypium*

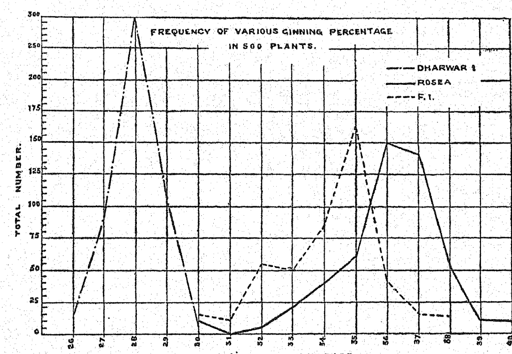

Fig. 6.

neglectum (var. *rosea*) parent has already been given in a previous chapter (page 80), but may be repeated (now calculated for 500 plants) side by

[1] *Loc. cit.*, p. 145. It has been suggested that the lint index, *i.e.*, the amount of lint per 100 seeds, should be used instead of the ginning percentage. There is no advantage in doing this in the present case, as the seed weight of each of the two types is practically identical.

side with a similar table for the other parent and for 450 plants of the resulting cross (F_1) as follows :—

Ginning percentage	Dharwar No. I	*Rosea*	F_1
26	15	..	..
27	90	..	..
28	285	..	..
29	105	..	..
30	5	10	15
31	..	..	11
32	..	5	54
33	..	20	50
34	..	40	84
35	..	60	161
36	..	150	42
37	..	140	15
38	..	55	18
39	..	10	..
40	..	10	..

The mode and mean ginning percentage in each case is as follows :—

Name of cotton	Mode per cent.	Mean per cent.
Dharwar No. I	28	28
Rosea	36–37	35·1
F_1	35	34·2

It will thus be seen that the high ginning percentage of the *rosea* parent, while not apparently completely dominant, yet gives a progeny which approaches it closely in this character, and indicates that it is largely prepotent so far as this quality is concerned.

In the F_2 generation, the following table shows the number of plants with various ginning percentages, the F_1 figures being repeated for comparison.

Ginning percentage	F_1	F_2
23	..	6
24	..	13
25	..	20
26	..	11
27	..	22
28	..	31
29	..	23
30	15	72
31	11	51
32	54	41
33	50	82
34	84	24
35	161	35
36	42	30
37	15	19
38	18	2
39	..	1
40	..	13
41	..	2
42	..	1
43	..	1

If, by analogy with the parents, all these plants are considered as having a low ginning percentage which have a percentage of 29 or below, and all above this point as having a high ginning percentage, the proportion in the various cases considered would be as follows :—

Dharwar No. I ..	99	per cent.	low ginning
Rosea ..	100	,,	high ginning
F_1	100	,,	high ginning
F_2	25·2	,,	low ginning
	74·8	,,	high ginning

The proportion between the plants yielding seeds giving high (above 29 per cent.) and those yielding seeds giving low (29 per cent. and below) is 2·9 to 1, almost exactly the proportion (3 : 1) which would be expected with a simple Mendelian pair of characters in which the high ginning character is dominant over the low ginning character.

The results in the F_3 generation enable this to be further studied, but as the year of growth was different (1920-21) from that in which the above figures were obtained, the records of ginning percentage for the parents and F_1 cross grown in the same year (1920-21) must be given.

Dharwar No. I ..	26 to 29 per cent.	Mode at 28 per cent.	Mean .. 27·5
Rosea ..	31 to 38 ,,	,, at 35 ,,	,, .. 34·3
F_1	30 to 38 ,,	,, at 35 ,,	,, .. 34·8

The characters of the seeds from the parents and from the F_1 generation remained therefore substantially identical with those grown in the previous

year. The F_3 generation gave results as follows, using seed from the high ginning plants of the F_2 generation in 14 cases and from the low ginning plants in one case. The records of seed from these fifteen plants are as follows :—

Plant No.		Seed planted	Number of plants		Proportion	
			High ginning	Low ginning	High ginning	Low ginning
High ginning	1	78	56	22	2·5	1
	2	91	69	22	3·1	1
	3	86	67	19	3·5	1
	4	74	61	13	4·6	1
	5	90	88	2	1	0
	6	73	54	19	2·8	1
	7	77	77	0	1	0
	8	45	36	9	4·0	1
	9	87	64	23	2·7	1
	10	56	39	17	2·3	1
	11	66	46	20	2·3	1
	12	70	52	18	2·8	1
	13	76	72	4	1	0
	14	89	69	20	3·4	1
Low ginning	15	77	3	74	0	1

There are evidently two types of plants among those which gave high ginning seeds in the F_2 generation. Nos. 1-4, 6, 8-12 and 14 gave, taken together, 3·1 high ginning plants to 1 low ginning plant. Nos. 5, 7 and 13, on the other hand, gave to all intents and purposes only plants yielding high ginning seeds and appeared to be pure in this character. The progeny from the single low ginning plant sown gave substantially pure low ginning seeds. So that the records for this (F_3) generation of the parent cross confirm the idea that the high or low ginning characters behave as a simple Mendelian character, the high ginning character being dominant over the low ginning. This is an exceedingly important result, and leads to a conception that it may be possible to combine a high ginning type of seed with one of long staple, if the latter proves to be also a Mendelian character.

The F_4 generation grown in 1921-22 has enabled the study of the inheritance of the ginning percentage, or in other words, of the amount of lint per seed, to be carried a stage further. The progeny of twenty-four plants of the F_3 generation has been obtained and studied as follows :—

(1) Four plants from the progeny of No. 5 and seven plants from the progeny of No. 7 in the above table which were presumably entirely pure in the high ginning character.

(2) Six plants from the high ginning progeny of No. 2 and seven plants from the high ginning progeny of No. 14, which gave in the F_3 generation the Mendelian proportion of 3 high ginning to 1 low ginning descendants.

The standard of 'low' to 'high' ginning character was unchanged from that adopted in the previous year, as a further growing of the parents of the cross showed, and the results obtained were as follows :—

(1) *Pure high ginning plants of F_3 generation.*

Plant No.	Total number of plants	Number of plants		Proportion	
		High ginning	Low ginning	High ginning	Low ginning
1	49	49	..	1	..
2	36	36	..	1	..
3	41	41	..	1	..
4	44	43	1	1	..
5	54	54	..	1	..
6	32	32	..	1	..
7	43	43	..	1	..
8	45	44	1	1	..
9	41	41	..	1	..
10	70	70	..	1	..
11	54	54	..	1	..

Thus practically the whole 507 out of 509 of the plants derived from those supposed to be pure in this character in the F_3 generation have yielded purely high ginning seed. The two plants which seem exceptional gave as follows :—

Limit of high ginning	.. ..	30 per cent.
1	.. .. ..	28 ,,
2	.. .. ..	29 ,,

(2) *High ginning plants of the F_3 generation from parents yielding both high and low ginning progeny.*

Plant No.	Total number of plants	Number of plants		Proportion	
		High ginning	Low ginning	High ginning	Low ginning
1	54	36	18	2·0	1·0
2	51	40	11	3·6	1·0
3	49	38	11	3·4	1·0
4	47	37	10	3·7	1·0
5	41	33	8	4·1	1·0
6	43	42	1	1·0	..
7	51	38	13	2·9	1·0
8	31	22	9	2·5	1·0
9	26	26	..	1·0	..
10	41	32	9	3·5	1·0
11	26	21	5	4·2	1·0
12	37	27	10	2·7	1·0
13	43	42	1	1·0	1·0

Three plants have given progeny pure in the high ginning character. The remainder have given descendants with both high ginning and low ginning characters in the proportion (on the total)—

High ginning : Low ginning :: 3·1 : 1.

Only three of the plants gave progeny whose proportion was seriously different from the expected percentage of 3 to 1. These were plants Nos. 1, 5, and 11. No. 11 was in a line seriously attacked by wilt, and as in the case also of No. 8 it perhaps ought to be eliminated from the comparison. The cases of Nos. 1 and 5 are not yet understood, and the seed obtained from these plants will need further study.

But on the whole the important result derived from a study of the F_3 generation that the proportion of lint to seed is a simple Mendelian character seems confirmed, and this suggests more clearly even than before the possibility of a cotton type with high ginning character and also long staple.

One question remains, however. Have the plants, pure in the high ginning character, as high a ginning percentage on the average as the high

ginning type of the F_1 generation from which they are descended? The following table gives the result of a study of this point first in the F_3 and then in the F_4 generation.

F_3 generation (1920-21).

Ginning percentage	F_1	Progeny of F_2		
		Plant No. 5	Plant No. 7	Plant No. 13
28	..	..	0	1
29	..	2	0	2
30	15	0	1	8
31	11	1	7	12
32	54	3	8	12
33	50	15	13	22
34	84	13	22	14
35	161	19	12	2
36	42	22	9	1
37	15	9	2	1
38	18	4	2	1
39	..	2	1	..
40	..	0	0	..
Total ..	450	90	77	76
Mode	35	36	34	33
Mean	34·2	34·9	34·2	32·3

F_4 generation (1921-22).

Ginning percentage	F_1	Progeny of eleven plants
28	..	..
29	..	..
30	12	9
31	5	30
32	46	47
33	81	64
34	130	76
35	104	127
36	71	70
37	17	34
38	20	25
39	14	17
40	..	10
Total ..	500	509
Mode ..	34	35
Mean ..	34·5	34·7

The progeny, therefore, maintains both in the third and fourth generations of the cross the proportion of lint found in the high ginning type of the F_1 generation.

(G) Length of staple.

In any breeding of cotton for the market, the staple of the resulting product is one of the three primary considerations. The yield of the crop in the field is perhaps the primary consideration for the farmer, the ginning percentage largely concerns the merchant who purchases seed cotton (*kapas*), but the staple of the resulting lint is what chiefly determines its market value after ginning. Hence, from the beginning, the question of improving the staple or of combining staple with other good qualities has interested workers on this question. Thus, as noted above, Fletcher[1] studied the question and found that length of lint (staple) is a dominant Mendelian character and this opinion was confirmed by Fyson. Balls also agreed on this point from his Egyptian studies, and no account of further investigations has been so far published. The studies whose progress we now record were designed to confirm (or otherwise) these observations and also to ascertain how far the staple and ginning percentage were correlated with one another.

The staple of the lint from a type of cotton is variable according to the part of the seed from which it is taken, and it becomes necessary to define exactly how the measurements were made in the present case. The actual variations in different parts of the seed in the Dharwar No. I type were discussed in a previous memoir, and also the variation from year to year. In the case of the other parent (*rosea*) the variation was decidedly smaller in the different parts of the seed, and the variation of the fibres in different years was as follows :—

	Dharwar No. I	*Rosea*
	mm.	mm.
1919–20	22 to 33	12 to 21
1920–21	22 to 33	13 to 23
1921–22	24 to 36	12 to 24

In all measurements, therefore, the length of staple was judged by the fibres from the middle of the seed, and comparisons were only made between the produce of plants grown in the same season. Restricting comparisons

[1] See Chapter I, page 73.

in this way the following shows the staple of the two parents and the F_1 cross as grown (1) in 1919-20, (2) in 1920-21, and (3) in 1921-22.

		1919–20			1920–21	
		Dharwar No. I	*Rosea*	F_1	Dharwar No. I	*Rosea*	F_1
mm.							
10–12	..	..	20	..	..	..	..
13–15	..	..	115	..	..	81	..
16–18	..	..	335	..	..	95	..
19–21	..	..	30	..	..	220	..
22–24	..	60	..	60	21	104	12
25–27	..	180	..	225	181	..	157
28–30	..	210	..	155	223	..	277
31–33	..	50	..	60	75	..	54

		1921–22		
		Dharwar No. I	*Rosea*	F_1
mm.				
10–12	..	..	30	..
13–15	..	..	80	..
16–18	..	..	162	..
19–21	..	..	218	..
22–24	..	15	10	2
25–27	..	145	..	133
28–30	..	235	..	262
31–33	..	105	..	83
34–36	..	..	..	20
Total	..	500	500	500

It was evident, in fact, that we had considerably different conditions prevailing in the three years quoted, 1920-21 and 1921-22 were years more favourable to long staple than 1919-20. While in 1919-20 all the low staple cotton had a lint length of below 21 mm. and all the high staple higher than this, in 1920-21 and 1921-22 the line of demarcation was at 24 mm., all the short staple cotton (*rosea*) being below this, and 96 and 97 per cent. respectively, in the two years, of the long staple cotton (Dharwar No. I) being above. The mode and mean of the length of staple in the three years was as follows :—

		1919–20		1920–21		1921–22	
		Dharwar No. I	*Rosea*	Dharwar No. I	*Rosea*	Dharwar No. I	*Rosea*
		mm.	mm.	mm.	mm.	mm.	mm.
Mode of length of staple	..	30	18	30	21	30	21
Mean length of staple	..	28·5	16·8	29·2	20·0	29·4	19·2

The F_1 generation followed the length of lint of the long staple cotton and gave in the three years the following figures :—

	1919–20 F_1	1920–21 F_1	1921–22 F_1
	mm.	mm.	mm.
Mode of length of staple	27	30	30
Mean length of staple	28·2	29·1	29·7

This showed a staple almost but not quite as long as that of the Dharwar No. I parent, and indicates the dominance of high staple over low staple between these two types of cotton.

The behaviour of the cross in the F_2 generation was peculiar, and indicated that some influence was present which prevented the distribution of the staple in accordance with what would be expected with a simple Mendelian factor. The figures obtained were in fact as follows :—

	1919–20	
	F_1	F_2
mm.		
13–15	..	19
16–18	..	67
19–21	..	132
22–24	60	144
25–27	225	106
28–30	155	31
31–33	60	1
Total ..	500	500

Thus we have 282 plants of long staple (*i.e.*, above 21 mm.) and 218 plants of short staple (*i.e.*, below and including 21 mm.) or a proportion of 1·6 to 1.

But at this point a reference may be made to the *colour* of *kumpta* cotton in general, and to that of Dharwar No. I in particular, which in this respect is like the rest of the variety. The cotton lint, as has already been described, is not white, but a dull white with a tinge of red, and this is continued in the

F_1 generation. But in the F_2 generation the colour segregates, and plants appear which give pure white cotton, and others which give lint with a deep brown tint. The proportion of these colours in the F_2 generation is shown in the following table.

		Proportion
(1) No. of plants grown ..	500	
(2) Plants yielding pure white cotton	180	1·5
(3) Plants yielding dull white cotton	200	1·6
(4) Plants yielding brown cotton ..	120	1·0

The distribution, it will be seen, does not conform to any simple law, but the secret both of the distribution of colour and of the relative proportion of long and short staple in the plants of this generation seems to be found in a very close connection between the brown colour and short staple in the lint. Thus of all the plants yielding brown lint, the staple of the cotton was as follows :—

mm.	Frequency (1919–20)
13–15	14
16–18	54
19–21	49
22–24	3
Total	120

Thus it will be noticed that 97·4 per cent. of the plants yielding brown lint also give lint which classes as short in staple, while of the remainder the lint only just exceeded the length necessary to bring it into the longer class.

Seeing that the correlation between brown colour and short staple is so complete, it may be assumed* that the presence of the brown colour has interfered with the normal operation of the Mendelian law, and that all plants which have a brown colour have been necessarily drawn into the short staple class. If from the 500 plants of the F_2 generation, the 120 plants which give a deep brown cotton are removed, the remainder give a distribution of the staple as follows :—

	Plants
Long staple (*i.e.*, over 21 mm.) ..	279
Short staple (*i.e.*, 21 mm. or below) ..	101

This gives a proportion of 2·7 to 1, or very nearly the relationship required for a single simple Mendelian factor.

* It is not suggested that this assumption is proved as it has not been possible to follow the matter further in the succeeding generations.

This argument could have been tested if in the F_3 generation only brown or dull white cottons were taken for further cultivation, but this could not be done, and only plants giving pure white coloured lint were grown in this generation. As pure white colour in the lint behaves as a pure recessive character, no further complications due to the brown element in the lint now arose.

The seeds from fifteen such plants yielding pure white lint were selected for growing in the F_3 generation, fourteen from plants yielding long staple, and one from a plant yielding a short staple cotton. The results from each of these plants as grown in 1920-21 are shown below :—

I. High stapled plants.

Plant No.	Number of seeds grown	Long staple (*i.e.*, over 24 mm.)	Short staple (*i.e.*, below 24 mm.)	Proportion	
				Long staple	Short staple
1 ..	90	88	2	1	..
2 ..	66	59	7	1	0·12
3 ..	89	89	..	1	..
4 ..	77	77	..	1	..
5 ..	78	60	18	3·3	1
6 ..	91	67	24	2·8	1
7 ..	86	62	24	2·6	1
8 ..	84	67	17	3·9	1
9 ..	73	51	22	2·3	1
10 ..	77	58	19	3·0	1
11 ..	87	62	25	2·5	1
12 ..	56	31	25	1·2	1
13 ..	70	48	22	2·2	1
14 ..	76	59	17	3·5	1
II. Low stapled plant.					
15 ..	45	1	44	0	1

If plant No. 2 above be eliminated, and possibly also plant No. 12, where the number of successful plants is small and hence the proportion is likely to be unsatisfactory, we have :—

(1) Three plants apparently pure as to high staple.

(2) Nine plants giving both long and short staple progeny in the proportion, on the average, of 2·9 to 1, or very nearly the expected Mendelian ratio, if long staple is a pure dominant.

From a plant yielding pure white cotton and giving short staple lint, the progeny was entirely short staple and pure white. In other words, both these characters behave as pure Mendelian recessive characters.

It appears, moreover, that once the brown coloured cottons are eliminated, the staple behaves as a simple Mendelian character.

All the plants giving purely what have been called long stapled cottons are not, however, equal as the following statement of the length of the staple in three such cases showed.

	Plant 1	Plant 3	Plant 4	F_1
mm.				
22–24	2	0	0	12
25–27	60	64	25	157
28–30	25	25	42	277
31–33	3	0	8	54
34–36	0	0	2	0
	90	89	77	500
	mm.	mm.	mm.	mm.
Mode	25–27	25–27	28–30	30
Mean	27·9	27·8	29·3	29·1

Thus only in plant No. 4 is there no sign of regression. The others show decided symptoms of reduction in staple from that reached by the dominant parent (Dharwar No. I) or the F_1 generation grown in the same year. Exactly what this means is not clear, but the study of the F_4 generation in 1921-22 has enabled further light to be thrown on the subject.

In the F_4 generation the whole of the seed produced by twenty-four plants of the F_3 generation was grown. Of these fourteen were from plants (Nos. 1 and 3 in the table on page 126) which in the F_3 generation appeared to breed entirely true in the long staple character. The remainder, ten in number, were from plants (Nos. 5 and 6 in the table) which while giving them-

selves long staple cotton, were from parents which also gave short staple producing plants. The results are shown in the following two tables :—

I. *Progeny of plants apparently pure in long staple character.*

Plant No.	Number of plants	Long staple (over 24 mm.)	Short staple (under 24 mm.)
		From Plant No. 1.	
1 ..	53	50	3
2 ..	51	49	2
3 ..	48	46	2
4 ..	47	42	5
5 ..	41	38	3
6 ..	43	41	2
7 ..	51	51	0
		From Plant No. 3.[1]	
8 ..	54	54	0
9 ..	32	32	0
10 ..	43	43	0
11 ..	45	42	3
12 ..	41	41	0
13 ..	70	68	2
14 ..	54	52	2

In the case of the results derived from Plant No. 1, the proportion of short staple plants seems higher than might be expected, but the whole of those so classed had a staple between 22 and 24 mm. and so really came within the range of the original long staple parent in the 1921-22 season. If this is taken into account, it may be said that the whole of the progeny of these two plants, apparently pure for staple characters in the F_3 generation, prove to retain that character in the succeeding year.

II. *Progeny of plants not pure in the long staple character.*

Plant No.	Number of plants	Long staple (over 24 mm.)	Short staple (under 24 mm.)
		From Plant No. 5.	
1 ..	49	37	12
2 ..	36	29	7
3 ..	41	41	..
4 ..	34	27	7
		From Plant No. 6.	
5 ..	31	24	7
6 ..	26	24	2
7 ..	41	30	11
8 ..	26	19	7
9 ..	37	29	8
10 ..	43	43	..

We have therefore a splitting taking place. Nos. 1, 2, 4, 5 and 7, 8 and 9 still retain both the long and short staple character, the proportion being :—

Long staple : Short staple : : 3·3 : 1.

This is close to the expected Mendelian ratio. The remainder (Nos. 3, 6 and 10) are pure in the long staple character and breed true.

The result, therefore, of these cultures in the F_4 generation is to confirm the conclusions already reached by a study of the previous one. The staple character is hereditary, and provided disturbing characters such as that of the brown colour of the lint are excluded the long staple character is dominant in these cottons, as was long ago claimed by Fletcher, Fyson and Balls.

But is there any regression from the standard of the F_1 generation ? This was, as has already been noted, suspected from the results of 1920-21 (F_3). But this year there is little sign of it as the following cases show :—

	Progeny of Plant No. 1	Progeny of Plant No. 2	F_1
mm.			
22–24 ..	17	7	2
25–27 ..	139	121	133
28–30 ..	172	187	262
31–33 ..	5	26	83
34–36 ..	0	0	20
Mode ..	30	30	30
Mean	28·6	29·4	29·7

(H) Correlation between ginning percentage and staple.

It is always assumed by practical men who are working with Indian cottons, that there is a definite correlation between a high ginning type of cotton and a low staple and *vice versâ*, or in other words that it is difficult if not impossible to obtain a long staple cotton which has also a high ginning percentage. Although there is no direct evidence that there is any necessity for this, it is curious to see how nearly all if not all the long staple cottons have, in fact, a small ginning percentage, and to this extent the opinion is justified by existing facts. But the characters of the cross now being studied seem to throw some light on the question, and hence the relationship between the two characters in the F_2, F_3 and F_4 generations may be given.

In the F_2 generation the general distribution of staple and ginning percentage is shown in Fig. 7. It will be remembered that the Dharwar No. I parent had long staple and a low ginning percentage, the

STAPLE

SHORT LONG

GINNING PERCENTAGES. LOW … HIGH

	·5	·6	·7	·8	·9	1·0	1·1
22	- I	1	2	-	1 II	-	-
23	-	-	3	2	1	-	-
24	1	2	2	1	3	1	-
25	2	3	3	1	7	9	-
26	1	4	3	3	4	1	-
27	1·	3	3	4	8	7	-
28	1	2	-	1	21	13	-
29	-	4	3	5	11	2	1
	III				IV		
30	4	13	8	7	29	29	-
31	6	5	11	8	30	19	-
32	3	6	10	4	14	25	-
33	5	7	11	33	46	5	-
34	-	8	3	9	11	4	-
35	2	7	4	15	18	4	-
36	-	4	3	8	19	4	-
37	3	2	3	8	8	1	-
38	1	-	-	2	-	-	-
39	-	-	-	-	2	-	-
40	-	1	2	2	5	1	-
41	-	-	-	-	3	-	-
42	-	-	-	2	-	-	-
43	-	-	-	-	2	-	-

FIG. 7.

rosea parent had short staple and a high ginning percentage, and the F_1 generation of the cross had long staple and a high ginning percentage. In the

F_2 generation the plants obtained were in the following proportion, excluding the plants producing brown tinted cotton referred to above.

Total number of plants	673
(1) High ginning and long staple	391
(2) High ginning and short staple	132
(3) Low ginning and long staple	106
(4) Low ginning and short staple	44

The proportion between these types was therefore

(1): (2): (3): (4) as 8·8: 3·0: 2·5: 1.

This is almost exactly the proportion which would be expected if we had to deal with two simple characters varying independently, and does not suggest any close correlation betwen the ginning quality and the "staple" character. The coefficient of correlation works out as 0·05, or in other words the characters are varying independently.

This is confirmed by the behaviour in the F_3 generation, where a series of plants have been grown from parents which were of high ginning and long staple character in the F_2 generation, but which contained elements both of high and low ginning, and of long and short staple in their genetic composition. The relation between the plants of various characters is shown in the following table :—

Plant No.	Total plants	Number of plants				Proportion			
		H. G. L. S.	H. G. S. S.	L. G. L. S.	L. G. S. S.	H. G. L. S.	H. G. S. S.	L. G. L. S.	L. G. S. S.
1 ..	78	43	13	17	5	8·6	2·6	3·4	1·0
2 ..	91	51	18	16	6	8·5	3·0	2·6	1·0
3 ..	86	48	19	14	5	9·6	3·8	2·4	1·0
4 ..	84	49	12	18	5	9·8	2·4	3·6	1·0
5 ..	73	36	18	15	4	9·0	4·5	3·7	1·0
6 ..	87	44	20	18	5	8·8	4·0	3·6	1·0
7 ..	70	34	18	14	4	8·5	4·5	3·5	1·0
Total ..	569	305	118	112	34	9·0	3·2	3·3	1·0

The proportion on this total is, therefore, as follows :—

High ginning and long staple	9·0
High ginning and short staple	3·2
Low ginning and long staple	3·3
Low ginning and short staple	1·0

5

This again is almost exactly the proportion which would be expected if we had to deal with two simple characters varying independently, and does not suggest any close correlation between the ginning quality and the staple characters.

The results obtained in the F_4 generation are equally in agreement with this conclusion. In this case four groups of plants were examined, whose genetic constitution with regard to the features under consideration were known from their behaviour in the previous generation. The results of growing the progeny of these four groups of plants were as follows :—

I. *Parents which, in the F_3 generation, appeared genetically pure in high ginning and long staple characters.*

Total number of plants	339
(1) High ginning and long staple	332
(2) High ginning and short staple	6
(3) Low ginning and long staple	none
(4) Low ginning and short staple	1

Substantially all gave progeny pure in the characters carried by the plants.

II. *Parents which, in the F_3 generation, appeared genetically pure in high ginning character, but not in staple character.*

Total number of plants	145
(1) High ginning and long staple	114
(2) High ginning and short staple	31
(3) Low ginning and long staple	none
(4) Low ginning and short staple	none

Low ginning plants are totally absent in the progeny and the proportion of

Long staple to short staple is 3·7 to 1.

This is a little higher than the expected ratio, but the number of plants involved is small.

III. *Parents which, in the F_3 generation, appeared genetically pure in long staple character, but not in ginning character.*

Total number of plants	292
(1) High ginning and long staple	221
(2) High ginning and short staple	none
(3) Low ginning and long staple	71
(4) Low ginning and short staple	none

Short staple plants are absolutely absent in the progeny and in long staple plants high ginning and low ginning are present in the proportion of 3·1 to 1.

This is practically identical with the expected ratio.

IV. *Parents which, in the F_3 generation, appeared genetically pure neither in ginning nor in staple characters.*

Total number of plants	135
(1) High ginning and long staple	78
(2) High ginning and short staple	24
(3) Low ginning and long staple	24
(4) Low ginning and short staple	9

The proportion between these types was, therefore,

(1) : (2) : (3) : (4) as 8·7 : 2·7 : 2·7 : 1.

We are entitled, therefore, as a result of our studies of four generations of the cotton cross between pure lines of *Gossypium herbaceum* (Dharwar No. I) and *Gossypium neglectum* var. *rosea* to consider that both the ginning and the staple characters of cotton are hereditary, and that they behave as genetically independent characters. This is a conclusion of very great importance, as, if it proves generally true, it would seem to make possible the development of high ginning types of cotton with long staple, and if this can be done it will bring into the range of probability very much higher returns from many Indian cottons than have hitherto been deemed likely. Such cottons will at once satisfy the demands of the cotton trade for a good staple cotton, and of the cultivators for one which gives a large percentage of lint to the seed cotton.

ACKNOWLEDGMENT.

I am very much indebted to Dr. Harold H. Mann, Director of Agriculture, Bombay, for kindly working out this paper from the results obtained by me. My acknowledgments are also due to Mr. T. Gilbert, Deputy Director of Agriculture, for advice, and to Messrs. V. M. Chavan and R. C. Joshi, my assistants, for their help in the measurement work.

CONTENTS

Plates I and III.

On account of carelessness on the part of the Calcutta Phototype Company in printing the final copies, Plate I (two-colour portion) is defective but gives an idea of the point illustrated.

Plate III has suffered so much in the final printing that it is useless for showing the range and distribution of colour in the stamens and styles.

STUDIES IN INDIAN OIL SEEDS No. 2. LINSEED.

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I. INTRODUCTION.

In India, linseed (*Linum usitatissimum* L.) is grown entirely for the oil in its seeds which form an important item in the export trade. After the Argentine, this country takes the second place in providing the world's supply of linseed oil. The chief centres of production are Bihar and Orissa (165,000 tons), the United Provinces (162,000 tons), Central Provinces and Berar (67,000 tons), Bengal (16,000 tons), Bombay (10,000 tons) and Hyderabad (8,000 tons).[1] The total average production of the last five years (1918 to 1922) was 374,600 tons. The seeds are exported chiefly from Calcutta and Bombay. The most important factor in the distribution of linseed in India appears to be the soil type. The crop flourishes best on deep, moisture retaining soils in tracts where the temperature of the cold season is favourable.

Although none of the indigenous forms of linseed are cultivated for the flax in the stem, nevertheless the possibility of combining the production of linseed with the supply of flax and also of the establishment of a fibre industry

[1] *Estimates of Area and Yield of Principal Crops in India,* 1921-22. Calcutta, 1923.

have been the subject of numerous experiments in India for the last hundred and fifty years. The results of the earlier experiments are summed up in the *Dictionary of Economic Products of India* (V, pp. 10-35) while accounts of the recent trials at Dooriah and Cawnpore are published in Bulletins 25, 30 and 35 of the Agricultural Research Institute, Pusa and in the *Agricultural Journal of India*.[1,2] In these flax trials, seed imported from Europe was employed and in many cases a satisfactory fibre was obtained. So far, however, no industry has resulted, largely on account of (1) the probable necessity of storing the produce during the rains till the temperature falls sufficiently for retting to take place and (2) of importing fresh seed for sowing at frequent intervals. These difficulties place flax cultivation beyond the means of the ordinary cultivator and can only be overcome by capitalists who are prepared to purchase the crop from the growers at harvest time in April and to store it till the following autumn, at the same time supplying the cultivators with suitable seed for sowing every October. Whether such an arrangement would work in practice and whether it would be found to be remunerative to all concerned cannot be stated with certainty.

In order to obtain the types of linseed grown in India, samples of the various grades of commercial linseed were supplied to us by Messrs. Ralli Brothers from their more important buying centres. In addition, a few parcels were obtained from the neighbourhood of Pusa and also from some of the Government farms in India. The samples obtained were as follows :—

TABLE I.

Trade samples of Indian linseed.

Name of centre	Description	By whom supplied
Sitamarhi ..	Small brown	Messrs. Ralli Brothers, Calcutta. These are the most important linseed centres for the Calcutta trade and are given in order of merit as regards linseed production.
Darbhanga ..	Do.	
Bettiah ..	Do.	
Patna ..	Two samples—small brown and bold brown..	
Arrah ..	Do. do. do ..	
Chauri Chaura ..	Small brown	
Khagaria ..	Do.	
Sasaram ..	Two samples—small brown and bold brown..	
Bhagalpur ..	Small brown	

[1] Coventry, B., Flax Experiments in India, *Agri. Jour. of India*, I, 1906, p. 192.
[2] Burt, B.C., Flax in the United Provinces, *Agri. Jour. of India*, XV, 1920, p. 616.

TABLE I.—(*continued*).

Name of centre	Description	By whom supplied
Indore ..	Three samples—yellow, bold yellow and brown and bold brown	Messrs. Ralli Brothers, Bombay. These are the most important linseed centres for the Bombay trade.
Saugor ..	Bold brown	
Damoh ..	Do.	
Cawnpore ..	Three samples—bold brown, medium brown and small brown	
Sutna ..	Medium brown	
Katni ..	Do.	
Nagpur ..	Three samples—bold yellow and brown, bold brown and medium brown	
Ahmednagar ..	Bold brown	
Jalna ..	Do.	
Aurangabad ..	Do.	
Latur ..	Do.	
Barsi ..	Do.	
Sholapur ..	Do.	
Sailu ..	Do.	
Sindewahi ..	Two samples—white (*rambha*) and red (*ghunkia*)	Superintendent, Govt. Farm, Sindewahi.
Nagpur ..	Local seed	Director of Agriculture, Central Provinces.
Hoshangabad ..	Two samples—red and white ..	Superintendent, Govt. Farm, Powarkhera.
Gurdaspur ..	Local seed	Deputy Director of Agriculture, Gurdaspur.
Srinagar ..	Two samples of Kashmir linseed ..	Director of Agriculture, Kashmir.
Pusa ..	Small brown	Villagers near Pusa.

The various samples were sown at Pusa in 1915 and a large number of single plants in each were selected and allowed to flower under muslin bags. The seeds of these plants were then sown in 1916 and single plants were again bagged. This procedure was continued for several years. The elementary species which remained after eliminating heterozygotes, were then studied and classified. At the same time the pollination of the flower was examined in detail and the amount of natural crossing determined. Some attention has been paid to the root system, to the effect of soil conditions on the growth of this crop and to the economic aspect. It has been possible to find among the types isolated some of great agricultural promise.

II. GENERAL BIOLOGY.

1. THE RELATION BETWEEN SOIL FACTORS AND THE TYPE OF LINSEED CULTIVATED.

Great differences have been observed between the types of linseed grown on the soils of Peninsular India (south of the line of the Ganges and the Jumna) and those cultivated on the Gangetic alluvium

The types of the Peninsula grow very rapidly at first at Pusa and the early formed leaves are large. The plants, however, lack vegetative vigour; branching is sparse; the stems soon become weak and procumbent and the early foliage is rapidly shed. This weakness in the stem persists throughout the growing period and at flowering time these sprawling plants stand out in strong contrast to the vigorous, erect types of the alluvium. The comparatively feeble growth of these forms is associated with very deep root development. All form large seeds rich in oil.

The varieties from the alluvium grow comparatively slowly at first but the stems are strong and rarely become procumbent. They are much branched and form abundant seed which is generally small and poorer in oil than in the Peninsular types. There is no loss of foliage and no sign of disease. The root system is usually shallow and abundant. In Fig. 1 the root systems of the

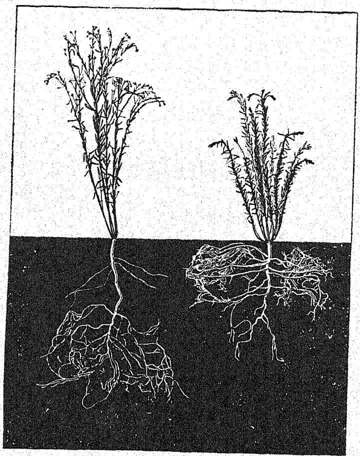
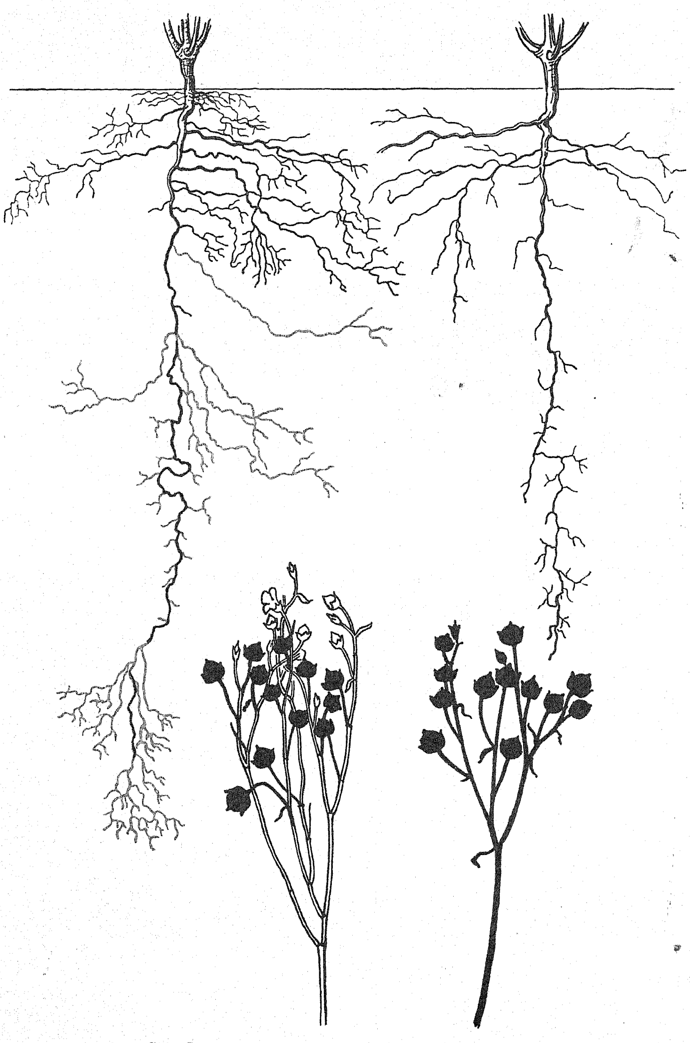


Fig. 1. Linseed from Central India (left) and the Indo-Gangetic alluvium (right).

two groups of linseed are shown. It will be seen that in the Peninsular type branching does not occur until the taproot has penetrated to some distance whereas in the type from the alluvium branching begins at once.



SECONDARY FLOWERING IN LINSEED.
Type 29 (left) shows secondary flowering and the corresponding root development.
These are absent in Type 34 (right).

The effect of long continued natural selection on the botanical composition of a crop is strikingly illustrated by the Indian linseeds. The deep rooted, large seeded, rapidly growing types of the Peninsula with few branches are admirably suited to make the most of the soil conditions of this tract where the surface cracks and rapidly dries and where the crop is dependent on the moisture of the lower layers. The growing season is short and soil moisture is apt to be a limiting factor. Rapid growth, few branches and large seeds are therefore obvious agricultural advantages. On the strong moist soils of the alluvium, where the upper layers are constantly moistened by the rise of moisture from the vast sea of underground water which exists about fifteen to twenty feet below the surface, early flowering combined with poor branching would be no advantage. There is ample time and sufficient moisture for extensive root development and for the maximum production of seed. This is confirmed by the yields obtained when unit species of these two groups are grown at Pusa. Even the best of the Peninsular types never produce the weight of seed given by the elementary species of the alluvium. The particular type of linseed grown in these two areas has obviously been determined by the soil factors.

2. Secondary flowering.

The effect of the type of root development on the sharpness of ripening is another interesting point which arose during the course of these investigations. Generally speaking, the varieties in Bihar ripen off sharply and definitely during the early part of the hot weather (15th March to 15th April). The exact time of ripening depends, as in other crops, on the advent and intensity of the hot winds which are prevalent at this season.

In most of the unit species of linseed, flowering ceases before the first formed capsules change colour. The sequence of maturation is as follows. The capsules ripen, turn brown and dry up first, then the upper branches turn brown and finally the main stem and basal branches lose their green colour and become dry. In certain types, however, although the capsules turn brown, the stems and branches retain their green colour and a second growth begins *after* the first set of capsules is ripe. The flowering is not continuous, the second flowering only starting after an interval. Such types flower, set seed and ripen their capsules in the ordinary manner and then, when the stems would normally turn brown, new leaves and flowers develop. The new growth and the whole plant eventually dries up owing to the increasing temperature and dryness. The young leaves and flowers with the ripe capsules growing side by side are shown in Plate I. The amount of secondary flowering varies in

different years and appears to depend on the amount of moisture in the soil. In 1923, a year in which the soil was exceptionally moist and hot winds were absent, this phenomenon was very marked. An examination was made *in situ* of the root systems of types growing side by side, some of which ripened off sharply while the others showed marked secondary flowering. It was found in all the cases examined that this secondary development was correlated with a deep root-system and active roots were found, mainly at a little distance below the surface. The roots in the other type were superficial and already dead. The root systems of these two types are shown in Plate I in which the active roots are represented in red.

In addition to the distribution of the roots it is probable that some other factor such as longevity is involved. The following eight types exhibited secondary flowering in 1923—Types 28, 29, 41, 46, 53, 56, 62 and 63. Six of these are late or very late.

No definite explanation can yet be given to account for the interval between the two periods of flowering. It may either be connected with some upward movement of the sub-soil water or it may be that when the first set of capsules has ripened off and ceases to require water, the small amount of moisture obtainable by the few active roots is just sufficient to re-start growth. Secondary flowering is important from an economic point of view for it is only the types which ripen off sharply which give an even sample and are easily threshed.

3. Soil conditions and growth.[1]

Some observations on the effect of changes in the soil conditions on the growth of linseed have been made in connection with certain experiments originally devised for another purpose.[2] The experiments were carried out in pit cultures[3] during 1921, 1922 and 1923. In 1921, a deep-rooted variety from Peninsular India (Type 94) was grown, in 1922 and 1923 a much branched, shallow-rooted type from the alluvium (Type 12). The effect on the height,

[1] In this section of the work valuable help was given by Babu Kashi Ram, Third Assistant in the Botanical Section, Pusa.

[2] *Agri. Jour. of India*, Special Indian Science Congress number, 1918. p. 36.

[3] In pit cultures, small plots, 5′ × 5′, are excavated to a depth of 18″ and the soil of all the plots is mixed, care being taken to keep the sub-soil and surface soil separate. This soil with the necessary additions of leaf-mould and potsherds is then replaced in the pits in as uniform a manner as possible. The pits are filled before the monsoon and the first crop is taken after the rain has consolidated them. This method obviates the well-known difficulties of pot cultures in tropical countries and is the only reliable method of exact field experiment we have discovered in a locality where the soil is so variable as at Pusa.

number of basal branches and yield of the addition of potsherds (to increase the æration), sodium nitrate and organic matter is shown in Tables II, III and IV. The leaf-mould and potsherds were added to the soil in 1919 once for all when the pits were filled. Sodium nitrate is added every year just before sowing by sprinkling it on the surface and mixing it with the upper soil. A crop of indigo was grown during 1919 and 1920, followed by linseed in 1921, 1922 and 1923

Table II.

The effect of soil aeration and organic matter on the height of linseed.

Soil treatment	1921 TYPE 94					1922 TYPE 12		1923 TYPE 12			
	No. of plants *	Average height in cm.				No. of plants	Average height in cm.	No. of plants	Average height in cm.		
		15-12-20.	10-1-21.	31-1-21.	At harvest		At harvest		28-11-22.	13-12-22.	At harvest
Control	27	13·6	28·9	44·3	47·7	143	51·6	98	9·0	17·8	62·6
Sodium nitrate @ 4 cwt. per acre	35	14·3	29·6	46·7	53·6	143	61·1	95	11·0	20·0	65·0
Soil $\frac{9}{10}$ + potsherds $\frac{1}{10}$ ..	36	12·4	28·8	44·7	49·3	146	50·0	98	9·3	17·6	61·3
Soil $\frac{8}{10}$ + potsherds $\frac{2}{10}$ ..	37	13·7	28·6	45·1	51·0	145	50·9	99	9·9	21·4	63·1
Soil $\frac{7}{10}$ + potsherds $\frac{3}{10}$ ..	34	15·4	33·0	47·7	53·7	144	53·2	98	10·8	21·4	64·8
Soil $\frac{7}{10}$ + leaf-mould $\frac{3}{10}$ ..	39	15·4	36·0	53·4	56·8	146	73·0	100	12·6	23·4	81·2
Soil $\frac{6}{10}$ + leaf-mould $\frac{3}{10}$ .. + potsherds $\frac{1}{10}$	38	15·1	37·6	55·4	60·6	146	69·8	28†	12·7	23·7	78·1
Soil $\frac{5}{10}$ + leaf-mould $\frac{3}{10}$ .. + potsherds $\frac{2}{10}$	37	16·2	37·9	57·9	65·1	146	75·7	101	13·0	24·2	80·4
Soil $\frac{4}{10}$ + leaf-mould $\frac{3}{10}$ .. + potsherds $\frac{3}{10}$	35	16·2	37·3	55·3	61·1	143	76·3	100	12·5	23·0	79·[illegible]

* This gives the number of plants measured, the actual number of plants per plot was 80.

† This plot was very badly attacked by white ants (*Termites*).

Table III.

The effect of soil aeration and organic matter on the branching of linseed.

Soil treatment	1921 Type 94		1922 Type 12		1923 Type 12			
	No. of plants	Average number of branches	No. of plants	Average number of branches	No. of plants	Average number of branches		
		At harvest		At harvest		2-11-22	13-12-22	At harvest
Control	27	1·4	143	6·2	98	1·6	4·1	6·4
Sodium nitrate @ 4 cwt. per acre	35	2·0	143	7·1	95	1·5	4·0	7·7
Soil $\frac{9}{10}$ + potsherds $\frac{1}{10}$ ..	36	1·7	146	6·8	98	1·6	5·4	7·5
Soil $\frac{8}{10}$ + potsherds $\frac{2}{10}$ ..	37	2·0	145	7·3	99	1·6	5·7	7·9
Soil $\frac{7}{10}$ + potsherds $\frac{3}{10}$ ..	34	2·2	144	6·8	98	1·8	5·6	9·1
Soil $\frac{7}{10}$ + leaf-mould $\frac{3}{10}$ ..	39	4·7	146	10·2	100	2·7	9·1	11·3
Soil $\frac{6}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{1}{10}$ ..	38	4·8	146	10·3	28	2·8	9·4	12·1
Soil $\frac{5}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{2}{10}$ ..	37	5·5	146	10·0	101	2·8	8·0	11·5
Soil $\frac{4}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{3}{10}$ ..	35	4·7	143	9·9	100	2·2	8·0	10·8

TABLE IV.

The effect of soil aeration and organic matter on the yield of linseed.

Soil treatment	1921 Type 94			1922 Type 12			1923 Type 12		
	No. of plants	Actual yield gms.	Yield per 36 plants gms.	No. of plants	Actual yield gms.	Yield per 140 plants gms.	No. of plants	Actual yield gms.	Yield per 100 plants gms.
Control	27	53	52	143	208	204	98	403	415
Sodium nitrate @ 4 cwt. per acre ..	35	82	84	143	292	286	95	557	586
Soil $\frac{9}{10}$ + potsherds $\frac{1}{10}$ ..	36	76	76	146	207	199	98	413	421
Soil $\frac{8}{10}$ + potsherds $\frac{2}{10}$ ..	37	89	87	145	238	230	99	437	441
Soil $\frac{7}{10}$ + potsherds $\frac{3}{10}$ ..	34	91	96	144	226	220	98	463	472
Soil $\frac{7}{10}$ + leaf-mould $\frac{3}{10}$ ..	39	163	150	146	517	496	100	980	980
Soil $\frac{6}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{1}{10}$ ..	38	176	167	146	448	430	28	249	889
Soil $\frac{5}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{2}{10}$ ..	37	224	218	146	515	494	101	868	859
Soil $\frac{4}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{3}{10}$ ..	35	177	182	143	413	404	100	847	847

TABLE V.

The development of nitrates in the experimental linseed plots.[1]

Soil treatment	Time of sampling	Moisture %			N as NO_3 in parts per million			N as NO_3 in pounds per acre		
		0-6″	6″-12″	12″-18″	0-6″	6″-12″	12″-18″	0-6″	6″-12″	12″-18″
Sodium nitrate @ 4 cwt. per acre	1st week, December 1920	12·10	11·96	11·87	31·83	1·24	0·79	43·23	1·67	1·08
	1st week, January 1921	6·32	9·43	10·21	33·44	0·43	2·07	45·42	0·58	2·81
	1st week, February 1921	6·43	8·30	8·98	37·58	0·42	0·34	51·03	0·57	0·46
Control	1st week, December 1920	12·43	11·70	12·14	2·75	1·06	0·53	3·74	1·43	0·72
	1st week, January 1921	7·19	9·49	10·58	2·39	0·43	0·43	3·25	0·58	0·58
	1st week, February 1921	10·19	8·53	9·93	1·21	0·34	0·17	1·64	0·46	0·23
Soil $\frac{7}{10}$ + potsherds $\frac{3}{10}$	1st week, December 1920	11·57	14·32	13·18	3·34	1·78	0·81	4·53	2·36	1·10
	1st week, January 1921	7·78	11·77	10·50	1·08	0·44	0·35	1·47	0·60	0·47
	1st week, February 1921	6·29	9·62	10·89	2·20	0·34	0·87	2·99	0·46	1·18
Soil $\frac{7}{10}$ + leaf-mould $\frac{3}{10}$	1st week, December 1920	15·24	18·51	18·29	21·28	26·23	29·05	28·9	35·62	39·45
	1st week, January 1921	9·47	13·35	15·20	20·45	19·81	22·19	27·77	26·90	30·14
	1st week, February 1921	7·25	11·75	11·48	22·72	29·04	28·92	30·86	39·43	39·28
Soil $\frac{4}{10}$ + leaf-mould $\frac{3}{10}$ + potsherds $\frac{3}{10}$	1st week, December 1920	16·34	18·35	19·80	12·22	18·90	35·67	16·60	25·67	48·43
	1st week, January 1921	11·72	16·49	19·31	18·47	13·20	22·62	25·08	17·92	30·71
	1st week, February 1921	10·13	14·15	16·32	23·22	18·67	22·56	31·53	22·35	30·64

Table V shows the amount of nitrogen present at the depth of 6,″ 12,″ and 18″ in the various plots.

It will be seen that the results of the three years are very consistent. The addition of aerating material causes a small increase in the height and in the number of branches. The increase in these two characters produced by the addition of 30 per cent. of aerating material is roughly equivalent to the in-

[1] These determinations were carried out by Mr. A. V. Iyer with the kind permission of Mr. F. J. Warth, Offg. Imperial Agricultural Chemist.

crease produced by the sodium nitrate. Sodium nitrate, however, has a much greater effect on the yield of seed. The most striking result is produced by the addition of organic matter either by itself or in conjunction with aerating material. The addition of 30 per cent. of leaf-mould has produced an increase of approximately 30 per cent. in the height, 100 per cent. in the number of basal branches and 250 per cent. in the weight of seed.

III. BIOLOGY OF THE FLOWER.

1. Flowering.[1]

The flowers open in the early morning and, as a general rule, in all such buds the folded corolla is visible the evening before. In rare cases, however, a flower opens in which the corolla is not apparent the previous evening. When the corolla becomes visible, the filaments are still short and the unburst anthers stand well below the slightly twisted stigmas. The rapid growth of the filaments, however, soon brings the anthers to the same level as the stigmas and this is the position when opening begins. The time of opening of the flowers depends chiefly on the temperature and humidity and to a less extent on the particular type. On warm mornings and when there is little or no dew, opening begins very early, while on cold dewy mornings the process is distinctly delayed.

In February 1916, the following observations were made on this point :—

Table VI.

Observations on the time of opening and closing of the flowers.

(1) February 9th. A cold day (max. temp. 70°F. ; min. temp. 30°F. ; temp. at 8 A.M. 47°F.).

No. of flower	Time of bursting of anthers	Time when opening of the flower was completed	Time of closing or shedding of petals	Time of re-opening of the flower the following day
1	9-59	11-15	16-30	10-12
2	10-00	10-55	16-30	10-13
3	9-58	11-20	16-30	10-11
4	9-52	11-30	16-30	10-10
5	9-56	11-45	16-30	10-05
6	9-52	12-00	16-30	10-08
7	9-51	11-25	15-40	....
8	9-37	10-45	16-30	9-46
9	9-00	10-47	16-30	10-02
10	9-42	10-58	16-00	....
11	9-39	11-43	15-45	....
12	9-30	10-45	16-30	9-40

[1] Howard and Howard, *Memoirs of the Dept. of Agri., Bot. Ser.*, X, 1919, p. 208.

(2) February 6th. A warm day (max. temp. 86°F.; min. temp. 53°F. temp. at 8 A.M. 61°F.).

No. of flower	Time of bursting of anthers	Time when opening of the flower was completed	Time of closing or shedding of petals	Time of re-opening of the flower the following day
1	8–15	8–31	17–00	8–00
2	8–31	8–40	16–00	....
3	8–12	8–29	14–30	....
4	8–15	8–27	16–00	....
5	8–59	8–27	16–00	....
6	8–24	8–35	15–00	....
7	8–14	8–40	13–30	....
8	8–15	8–40	14–30	....
9	8–13	8–36	13–30	....
10	8–08	8–27	15–00	....
11	8–13	8–40	13–30	....
12	8–17	8–33	13–00	....

Thus the opening is not only delayed on cold days but flowers often re-open the following morning and the petals do not fall till the second day. On February, 10th 1916, a very warm day, some flowers began to show signs of opening as early as 3 A.M., while on February 9th, a cold day, opening did not begin till 7-30 A.M. As a rule the flowers are fully open between 8-15 and 9 A.M. on normally warm days, and from 10 A.M. to 12 noon on cold days. The petals begin to fall on the day of opening and this is generally completed by 5 P.M. A few, however, re-open the following morning and the number is considerably increased on cold and cloudy days.

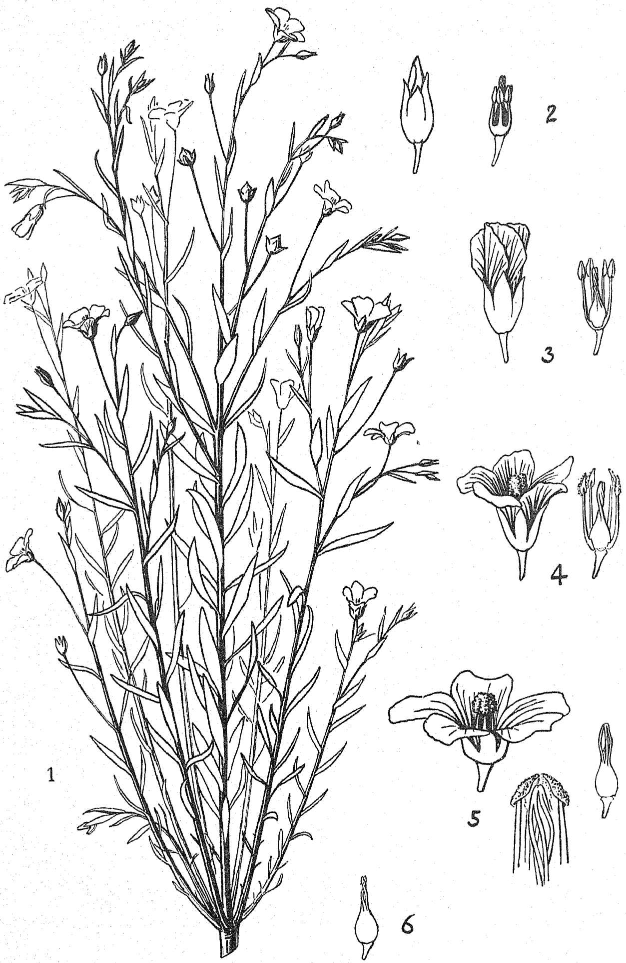
Observations on the flowering and pollination of European forms of *L. usitatissimum*, grown for fibre, have been published by Fruwirth.[1] A very full account of the morphology of the flower and of the details of flowering and pollination of such varieties has been recorded by Tammes.[2] The time of opening of the flower appears to differ considerably in Holland and in Bihar. Thus Tammes states that in the former country the flowers begin to open at 5 A.M. and to fall at 10 or 11 A.M. It is unusual to find a single flower after noon. She also states that the re-opening of the flower on the following day is extremely rare. Apparently the length of time the flower remains open is approximately the same as in India—about 5 hours.

2. Pollination.

The anthers begin to burst longitudinally when the flower is half open and at this period they stand at a little distance from the crowded stigmas and

[1] Fruwirth, C., *Die Züchtung der landw. Kulturpflanzen*, III, 1922, s. 45.

[2] Tammes, T., *Recueil des travaux botaniques Neérland.*, XV, 1918, p. 185.



INDIAN LINSEED.

1, a complete plant in flower. 2, a bud at 5 p. m. the day before opening. 3, an opening bud at 6-30 a. m. 4, a fully opened flower at 8 a. m. 5, self pollination at 9 a.m. 6, the style at 12 noon.

often at a slightly higher level (Plate II). A few minutes later when the flower is fully open and the rupture of the anthers is complete, they close in on the stigmas and self-pollination takes place. Thus self-pollination takes place automatically by the help of the expansion of the corolla. At a little later stage, the burst anthers often fall together forming a cap over the stigmas a movement which renders self-pollination a practical certainty. In many flowers it was observed that after the anthers begin to burst, twisting of the styles occurred which helped to move the burst anthers through 90° thus bringing their pollen-covered surfaces close to the stigmas. This twisting also brought the stigmas to a slightly lower level and so assisted the burst anthers to fall together and form a cap over the stigmas. In many cases these styles untwist after the anther cap is formed, a circumstance which still further favours self-pollination (Plate II).

3. Cross-fertilization.

Small bees visit the flowers for honey about 10 A.M. While collecting honey from the five nectaries, they occasionally come in contact with the burst anthers and with the stigmas so that cross-pollination is possible. That crossing may occasionally take place in India has been proved by a study of the cultures obtained from the seed of single plants.[1] In 1916, the seed of 340 bagged plants was sown of which 334 appeared to breed true. Splitting was observed in six cultures only—one gave rise to plants with flowers of different shades of blue while five cultures produced plants differing in habit of growth. In 1917, the seed of 233 bagged plants was sown. All seemed to breed true except one which split as regards habit and flower colour. In 1918, the seed of 232 bagged plants was sown all of which appeared to breed true. These observations indicate that in the field crossing is more frequent than would be suspected from a study of the flower. That this is so was confirmed by the results of sowing separately the unbagged seed of all the cultures raised in 1917. In these 233 cultures, stray plants were found in five cases as follows :—

No. 1 (white flowers). Two blue-flowered plants appeared which next year gave 84 blue and 32 white flowered plants in one case and 129 blue and 34 white in the other, or a total of 213 blues to 66 whites.

No. 23 (white flowers). One blue-flowered plant occurred which gave next year 52 blue-flowered and 12 white-flowered plants.

No. 165 (white flowers). One blue-flowered plant was found which next year gave 84 blue-flowered and 19 white-flowered offspring.

[1] For previous observations on the occurrence of natural cross fertilization at Pusa see *Mem. of the Dept. of Agri., Bot. Ser.*, III, 1910, p. 316.

No. 170 (pale blue flowers). One dark-blue flowered plant appeared which split as regards shape of petals, colour of pollen (white or yellow) and colour of petals—white and shades of blue from very pale to very dark blue. The ratio of total blues to whites was 264 : 7.

No. 217 (blue flowers). In this, three pale blues appeared which split next year into 8 blue and 348 pale blue, 4 blue and 133 pale blue and 4 blue and 276 pale blue.

A similar experience occurred in 1918. In 232 cultures from unbagged seed, a total of 15 stray plants were found in nine of these cultures. In all probability many of these were natural crosses.

These examples are sufficient to show that natural crossing is more common in Indian linseed than would be supposed from a study of the flower. The cases are sufficiently numerous to make it clear that in exact work with this crop all seed must be raised under bag. This does not interfere with setting and as far as our observations go there is no falling off in vigour produced thereby.

The mode of pollination of the European cultivated forms of linseed has been described in detail by Fruwirth[1] who found that self-pollination is the rule and that good setting is obtained under bag without loss of vigour in the succeeding generations. Less produce per plant is however obtained under bag than from free flowering plants. Vargas Eyre and Smith[2] have recently paid some attention in Great Britain to the mode of pollination in various species of *Linum* and sum up their results as follows :—" The flaxes are sometimes regarded as 'selfing' so readily that there is small chance of cross-pollination being effective. It seems quite clear, however, from the foregoing observations that this is not always the case and does not apply to the varieties of *L. usitatissimum* commonly grown and this view receives support from the fact that dimorphism occurs among the species of *Linum*. It is noticed that the pollen is somewhat adhesive in character and is produced only in relatively small quantities and it seems highly probable that the crossing which takes place is almost entirely caused by the insects which may be observed visiting the flowers freely." Bateson,[3] in experiments at the John Innes Horticultural Institute, found self-pollination to be the rule. Tammes[4] also records the occurrence of cross-fertilisation but states that it is infrequent.

[1] Fruwirth, *Die Züchtung der landw. Kulturpflanzen*, III, 1922, s. 45.
[2] Eyre, J. V. and Smith, G., *Jour. of Genetics*, V, 1916, p. 189.
[3] Bateson, W., *Jour. of Genetics*, V, 1916, p. 201.
[4] Tammes, T., *Recueil des travaux bot. Neérland.*, XV, 1918.

Parthenocarpy has been observed in *L. usitatissimum* by Tammes[1] especially where species hybridization was attempted. Parthenogenesis does not appear to occur.

IV. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

The examination of the Indian linseed crop has revealed a surprisingly large number of forms. These differ mainly in the amount and tone of the colour on the various organs of the flower. This colour (which is always some shade of blue or purple) is found on the filaments, anthers, styles and stigmas in addition to the corolla. Thus the filament may be entirely white or may be partly coloured, the tone varying from the palest blue to the deepest purple and the colour may be present in amounts varying from a small dot immediately below the anther to a coloration of the whole of the upper half of the filament. Similarly the amount of colour on the style may vary from a few blue lines to a complete deep blue coloration even extending to the stigma. Pure line cultures during a number of years have shown that the types breed true to minute differences of colour on the essential organs and that these can be safely used for classification purposes.[2]

It has not been considered advisable to make use of the European varieties proposed by Alefeld.[3] In the first place, the short, much branched Indian linseeds form a group quite distinct from the tall European forms. Secondly, the meagre descriptions which ignore the colour on the essential organs would make any assignment of doubtful value. The Indian linseeds have, therefore, been considered as a separate group and a classification based on easily recognizable morphological differences is given in this paper. The 121 elementary species isolated fall into 26 varieties. The characters used in differentiating the varieties are the colour of the seeds, corolla, filaments, anthers and styles and the size of the seeds. In general, it is a somewhat doubtful procedure to use size differences as varietal distinctions. The differences in the size of the seed in Indian linseeds are, however, so well marked that they form the basis of the commercial classification, which recognizes three classes—bold, medium and small. The types have been separated in the first instance by differences in the amount and tone of colour of the filaments, anthers, styles, stigmas and seeds. Habit differences, which naturally depend on environment, have only been used as a last resort.

[1] Tammes, T., *Recueil des travaux bot. Neérland.*, XV, 1918.

[2] See also Tammes, T., *Jour. of Genetics*, XI, 1922, p. 20.

[3] Alefeld—*Landw. Flora*, p. 102. We are much indebted to Dr. Carl Fruwirth, Professor at the Technische Hochschule, Vienna, for a transcript of these descriptions as the book was unobtainable in India.

1. Notes on the characters.

Habit. The general habit depends on three things—the height, the mode of branching and the foliage. The heights of the various unit species in 1923 varied between 41 and 71 cm. and as a general rule this character is not greatly influenced by the environment. Very tall forms, such as those grown in Europe, are not represented among the indigenous types. The Indian forms branch both from the base and also at a point higher up on the stem. The basal branches may be crowded giving an erect, compact appearance to the culture or they may be spreading when the plants possess an open habit of growth. As would be expected, the amount of branching is not constant but varies greatly according to the fertility of the soil. The potential branching power of a type is, however, a definite inherited character. In 1921, the average number of basal branches varied from two to fourteen among the 121 types when grown under equal conditions. The leaves in all cases are linear with smooth surfaces. In 1921, the length varied from 2·2 to 4·3 cm. and the breadth from 0·2 to 0·7 cm. There is some range in the colour of the foliage from green to bluish green but this is not considerable.

Period of growth. The types show very great differences in the length of the growth period and these differences can be utilized in classification. The seeds of the earliest kinds are nearly ripe before the late ones begin to flower. In 1923, the earliest type began to flower 47 days, the latest 81 days after sowing.

Flowers. There is a considerable range in the size of the flowers of the types, in the degree of opening and in the details of colouring. The petals vary from sub-linear to broad in which the length and breadth are equal. They fall into two classes—those with narrow and those with broad petals. The differences in the expansion of the flower between the types is considerable. In fully opened flowers with narrow petals, a certain amount of space is left between the petals whereas when the petals are broad they overlap forming a continuous corolla. The amount of opening of the flower also varies. There is every gradation between fully opened flowers and those which are only half open. A further complication occurs through the incurving of the edges of the petals or the folding of the whole petal. Although the amount of opening of the flowers and the degree of folding of the petals varies to some extent with the weather, nevertheless these differences are also characteristic of the types. The differences in flower colour depend on the general ground colour of the petals and also on markings which spread in a fan-shaped form from the base of the petal. These markings are due to the presence of a dark colour in the

veins, mostly in the lower part of the petal. In some flowers, as in Type 4, these are of the same colour as the petal and therefore inconspicuous; in others, they are darker in colour than the petal and are, therefore, conspicuous. This is particularly the case in Types 1, 2 and 3 where the markings are violet and the petals are white. In the corolla two colours—blue and pink—exist in varying proportions. The petals may be :—

(*a*) White—opaque pure white or semi-transparent bluish white.

(*b*) Pale blue—in which case the pink colour is absent or else very faint.

(*c*) Blue—in which case blue is predominant but with the pink factor present. There is a considerable range in blues.

(*d*) Violet. In these, pink predominates although blue is also present. The violet tones range from a bluish pink to a decided purple.

The presence of both blue and pink can be seen by the naked eye. Tammes[1], in a series of investigations, the results of which are summed up in a recent paper published in the *Journal of Genetics*, has identified six factors which influence the colour of the corolla. She has also been able to isolate a form with a pink corolla. This is not represented in India.

Andrœcium. The various parts of the stamens, including the pollen, exhibit interesting colour differences. The filaments are either white or white with various amounts of blue or purple. The colour may occur on one side of the filament only or may be diffused over the whole surface. In the latter case, various stages from a ring just below the anther to a complete coloration of the upper half of the filament can be found. Similarly, in the former case the amount varies from a dot immediately below the anther to a strip half the length of the filament. All stages of colour from pale blue through blues (including bright blue) to purple are represented. There is a similar range of colour in the anthers but these appear to show no connection with the colour scheme of the filament. The anthers are either white or white with a blue line or blue. Blue anthers may occur with white or with purple filaments. Examples of the various combinations may be seen in Plate III. The combination of pale blue anthers with purple filaments presents a very striking appearance.

The pollen appears white or of various shades of yellow but this difference is accentuated by the colour of the anther. A blue anther wall lessens the yellow appearance while a white wall intensifies it. This character has, therefore, not been used in the classification. No blue pollen such as occurs in the

[1] Tammes, T., *Jour. of Genetics*, XII, 1922, p. 19.

European forms has been observed. In a paper by Tammes[1] it is stated :— "In the blue anther, however, both wall and pollen are blue. Whether there are forms in which the pollen is yellow and the wall blue or the pollen blue and the wall colourless I have not yet investigated." The Indian linseeds give a large number of examples of the former (pollen yellow, wall blue) but none of the latter combination (pollen blue, wall colourless). In the present paper, the term 'anther blue' refers only to the colour of the wall of the anther.

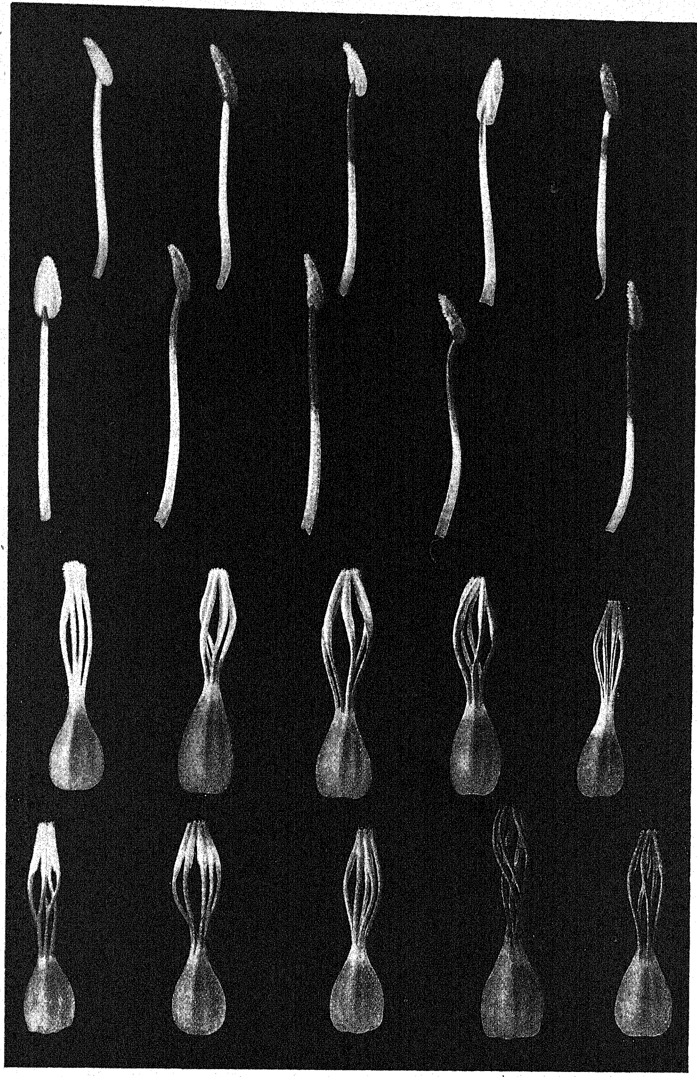
Gynœcium. The styles are either white or white with varying amounts of blue or purple. In contrast with the filaments the colour always spreads from the base upwards. The range is shown in Plate III.

The stigmatic surfaces are either white or purple or white tinged with varying amounts of pink or purple. The colour of the stigma is best seen under a lens when the flowers are receptive. This is a somewhat difficult character to determine as it changes with the age of the flower. The stigma is never coloured if the style is white, neither is a deep purple stigma ever found with a pale blue style. It may be said generally that the intensity of the colour of the stigma is always less than that of the style.

Seeds. The seeds vary in colour from pure yellow to brown. Two grades of yellow—pure yellow and yellow with a brownish tinge—and two grades of fawn can be distinguished. These facts and the occurrence of various degrees of brown suggest that several factors are likely to be involved in producing the deepest shades of brown. Tammes[2] states that the brown colour of the seed coat is produced by a complex of characters and that the yellow appearance of the seeds is due to the yellow colour of the cotyledons appearing through the colourless and transparent seed coat of those forms. Large seeded types occur in all these colours but the medium and small types are only associated with a brown seed coat. Investigations have shown that probably several factors are concerned in the determination of the size of the seeds.[3]

Correlations. It is of interest to see what evidence is afforded by this collection of linseeds on the question of correlation as regards colour among the parts of the flower. The following table shows that the colour of the corolla can be equally well associated with coloured or with white filaments, anthers and styles. Whether this independence is only apparent and is due to the presence of inhibiting factors in the various parts can only be determined by investigation of the genetics of this species.

[1] Tammes, T., *Jour. of Genetics*, XII, 1922, p. 19.
[2] Tammes, *loc. cit.*
[3] Tammes, T., *Rec. des. travaux bot. Neér,* VIII, 1911.



COLOUR DISTRIBUTION IN THE STAMENS AND STYLES OF LINSEED.

TABLE VII.

Correlation of characters.

A white corolla may be present with—	A blue corolla may be present with—
white or blue filaments	white or blue filaments
white or blue anthers	white or blue anthers
white or blue styles	white or blue styles
yellow, fawn or brown seeds	fawn or brown seeds
small or bold seeds	small, medium or bold seeds

A lilac or purple corolla may be present with—
- blue filaments
- blue or white anthers
- blue style
- fawn or brown seed
- small or bold seed

It is probably a chance that no medium-sized seeds are associated with white or lilac corollas as both small and bold seeds occur. The association of yellow seeds with a white corolla only may be also a coincidence as Tammes[1] has found blue-flowered, yellow-seeded linseeds. No connection can be traced between the colour of the anthers and that of the filaments and styles. White and blue anthers are found associated with both blue and white filaments and blue and white styles. White filaments occur with both white and blue styles. Blue filaments only occur with blue styles but this may be accidental. A correlation which will probably be found to be a true one is, however, the association of a coloured stigma only with a coloured style. In general, the examination of these Indian linseeds would point to the independence of the colour manifestations on the various parts of the flower.

2. Key to the Indian varieties of L. usitatissimum.

I. Seeds yellow.
  1. Corolla white.
    A. Anthers white.
      (*a*). Filaments blue.
        α. Styles blue.
          (1). Seeds bold.
            var. *luteum*.
              Types 1, 2, 3.

[1] Tammes, T., *Jour. of Genetics*, XII, 1922, p. 19.

II. Seeds fawn coloured.
- 1. Corolla white.
  - A. Anthers white.
    - (a). Filaments blue.
      - a. Styles pale blue.
        - (1). Seeds bold.
          - var. *lutescens*.
            - Types 4, 5.
- 2. Corolla light blue.
  - A. Anthers blue.
    - (a). Filaments pale blue.
      - a. Styles pale blue.
        - (1). Seeds bold.
          - var. *indicum*.
            - Type 6.
- 3. Corolla blue.
  - A. Anthers blue.
    - (a). Filaments blue.
      - a. Styles blue.
        - (1). Seeds bold.
          - var. *cyaneum*.
            - Types 7, 8, 9, 10.
- 4. Corolla deep purple.
  - A. Anthers blue.
    - (a). Filaments blue.
      - a. Styles blue.
        - (1). Seeds bold.
          - var. *purpureum*.
            - Type 11.

III. Seeds brown.
- 1 Corolla white.
  - A. Anthers white.
    - (a). Filaments white.
      - a. Styles white.
        - (1). Seeds small.
          - var. *albidum*.
            - Type 12.
        - (2). Seeds bold.
          - var. *album*.
            - Types 13, 14.

B. Anthers blue.
(*a*). Filaments white.
α. Styles white.
(1). Seeds small.
var. *albocæruleum*.
Type 15.

2. Corolla light blue.
A. Anthers white.
(*a*). Filaments blue.
α Styles blue.
(1). Seeds medium in size.
var. *officinale*.
Types 16, 17, 18.

B. Anthers blue.
(*a*). Filaments white.
α. Styles white.
(1). Seeds small.
var. *bengalense*.
Types 19, 20.

(2). Seeds bold.
var. *agreste*.
Types 21, 22.

β. Styles pale blue.
(1). Seeds small.
var. *meridionale*.
Type 23.

(*b*). Filaments blue.
α. Styles blue.
(1). Seeds small.
var. *gangeticum*.
Type 24.

(2). Seeds medium in size.
var. *laxum*.
Types 25, 26.

(3). Seeds bold.
var. *præcox*.
Type 27.

3. Corolla blue.
  A. Anthers white.
    (*a*). Filaments white.
      a. Styles blue.
        (1). Seeds small.
          var. *pratense*.
            Type 28.
    (*b*). Filaments blue.
      a. Styles blue.
        (1). Seeds small.
          var. *minor*.
            Types 29, 30, 31, 32.
        (2). Seeds bold.
          var. *herbaceum*.
            Type 33.
  B. Anthers blue.
    (*a*). Filaments white.
      a. Styles blue.
        (1). Seeds small.
          var. *pulchrum*.
            Type 34.
        (2). Seeds medium in size.
          var. *cæsium*.
            Type 35.
        (3). Seeds bold.
          var. *bicolor*.
            Type 36.
    (*b*). Filaments blue.
      a. Styles blue.
        (1). Seeds small.
          var. *commune*.
            Types 37 to 62.
        (2). Seeds medium in size.
          var. *campestre*.
            Types 63 to 80
        (3). Seeds bold.
          var. *vulgatum*.
            Types 81 to 117.

4. Corolla purple.
   A. Anthers white.
      (*a*). Filaments blue.
         a. Styles blue.
            (1). Seeds bold.
               var. *tinctorium*.
                  Types 118 to 120.
   B. Anthers blue.
      (*a*). Filaments blue.
         a. Styles blue.
            (1). Seeds small.
               var. *sativum*.
                  Types 121 to 123.

3. Description and key to the Types.

var. luteum.

Seeds yellow, bold. *Corolla* white with violet markings. *Stamens* anthers white, filaments blue. *Styles* blue.

1. Seeds pure yellow.

Type 1. Early, most of the branching at the base giving an open habit; average height 49 cm. *Foliage* light bluish green. *Flowers* very large, open; petals broad; filaments upper half blue; styles blue at the base, white above, stigmatic surfaces white with a pink tinge.

2. Seeds yellow with a brownish tinge.

Type 2. Very early, spreading, a medium amount of branching; average height 50 cm. *Foliage* light bluish green. *Flowers* large, open; petals broad; filaments upper half blue; styles blue below, white above, stigmatic surfaces white with a pink tinge.

Type 3. Medium in maturity, a medium amount of branching, open in habit; average height 56 cm. *Foliage* light bluish green. *Flowers* very large, open; petals broad; filaments upper half blue; styles blue below, white above, stigmatic surfaces white with a pink tinge.

These two types differ in the time of maturity and in the size of the flower.

var. lutescens.

Seeds fawn coloured, bold. *Corolla* white with violet markings. *Stamens* anthers white, filaments blue. *Styles* pale blue.

TYPE 4. Early, habit spreading; average height 48 cm. *Foliage* light bluish green. *Flowers* very large, very open; petals not very road; filaments upper third very pale blue; styles pale blue at the base white above, stigmatic surfaces white. *Seeds* lighter in colour than in Type 5.

TYPE 5. Medium in maturity, a medium amount of branching, open in habit; average height 50 cm. *Foliage* light green. *Flowers* large, very open; petals very broad; filaments upper third very pale blue; styles pale blue at the base, stigmatic surfaces white.

Type 4 is earlier than Type 5, the flowers are larger and the petals less broad with the markings less distinct. The seeds of Type 4 are also lighter in colour.

var. INDICUM.

Seeds fawn coloured, bold. *Corolla* light blue. *Stamens* anthers blue, filaments pale blue. *Styles* pale blue.

TYPE 6. Early, a good deal of branching from the base, open in habit; average height 49 cm. *Foliage* light green. *Flowers* medium in size, open; petals narrow; a clear blue of a light tone with very little pink colour present; filaments upper third pale blue; styles very pale blue, stigmatic surfaces white.

var. CYANEUM.

Seeds fawn coloured, bold. *Corolla* blue. *Stamens* anthers blue, filaments blue. *Styles* blue.

TYPE 7. Medium in maturity, a certain amount of branching from the base, habit erect; average height 49 cm. *Foliage* light bluish green. *Flowers* fairly large, open; petals broad, somewhat deep blue; filaments upper third pale blue, the colour mostly on one side; anthers pale blue; styles pale blue; stigmatic surfaces white with pink tips. *Seeds* yellowish in tone.

TYPE 8. Early, a good deal of branching both above and below, habit open but crowded; average height 47 cm. *Foliage* light green. *Flowers* medium-sized, open; petals narrow, a medium deep blue; filaments upper half blue; styles blue, stigmatic surfaces white, tips pink.

TYPE 9. Medium in maturity, very little branching from the base, somewhat spreading in habit; average height 48 cm. *Foliage* bluish green. *Flowers* medium in size; petals broad, somewhat deep

blue; filaments upper third blue; styles blue, stigmatic surfaces tinged with pale purple.

TYPE 10. Early, a medium amount of branching below, habit open average height 46 cm. *Foliage* bluish green. *Flowers* medium to small, not quite open; petals narrow, deep blue; filaments upper third bright blue; styles bright blue, stigmatic surfaces and tips purple.

These four types can be most easily distinguished by the depth of colour on the anthers, filaments and styles. In Type 7 this is pale blue, in Types 8 and 9 blue and in Type 10 bright blue with purple stigmatic surfaces. Types 8 and 9 can be separated by the breadth of their petals.

var. PURPUREUM.

Seeds fawn coloured, bold. *Corolla* deep purple. *Stamens* anthers blue, filaments blue. *Styles* blue.

TYPE 11. Early, a good deal of branching from the base, habit very open and spreading; average height 43 cm. *Foliage* light bluish green. *Flowers* medium in size, not very open; petals very narrow; filaments white except for a minute amount of blue colour just below the anther on one side only; styles deep blue throughout, stigmatic surfaces pale purple with deep purple tips.

var. ALBIDUM.

Seeds brown, small. *Corolla* white with light markings. *Stamens* anthers white, filaments white. *Styles* white.

TYPE 12. Late, much branched, very erect, crowded and compact in habit; average height 53 cm. *Foliage* dark green. *Flowers* small, do not open well; petals very narrow, tinged with blue; styles white, stigmas white.

var. ALBUM.

Seeds brown, bold. *Corolla* white. *Stamens* anthers white, filaments white. *Styles* white.

TYPE 13. Late, a small amount of branching below, a great deal above, habit erect, crowded and compact; average height 55 cm. *Foliage* dark green. *Flowers* small, never open fully; petals very narrow and never shed, an opaque white, markings not very apparent; filaments, styles and stigmas white.

TYPE 14. Medium in maturity, a small amount of branching below, a great deal above, habit somewhat spreading and open; average

height 60 cm. *Foliage* bluish-green. *Flowers* medium in size, open fully; petals thin, easily shed, white with a bluish tinge, markings faint but distinct, very narrow with very wide spaces in between; filaments, styles and stigmas white.

var. ALBOCŒRULEUM.

Seeds brown, small. *Corolla* white with light markings. *Stamens* anthers blue, filaments white. *Styles* white.

TYPE 15. Somewhat late, much branched, erect and very compact in habit; average height 62 cm. *Foliage* light green. *Flowers* medium in size, mediumly open; petals broad; styles white, stigmas white.

var. OFFICINALE.

Seeds brown, medium in size. *Corolla* pale blue. *Stamens* anthers white, filaments blue. *Styles* blue.

TYPE 16. Medium in maturity, a good deal of branching both above and below, habit somewhat spreading; average height 51 cm. *Foliage* light green. *Flowers* small, mediumly open; petals narrow, with much space in between; filaments with a very small amount of pale blue colour on one side; styles blue, stigmatic surfaces pale purple with purple tips.

TYPE 17. Medium in maturity, very little branching below but a great deal above, habit erect, crowded and compact; average height 57 cm. *Foliage* light green. *Flowers* small, half open; petals narrow; filaments upper third bright blue; styles blue, stigmatic surfaces pale purple, tips purple.

TYPE 18. Late, a fair amount of branching below, habit spreading with an open top; average height 48 cm. *Foliage* dark green. *Flowers* large, open; petals broad; filaments upper third blue; styles blue, stigmatic surfaces white.

In Type 18 the petals are broad, in Types 16 and 17 narrow. These two types can be distinguished by the amount of colour on the filaments. In Type 16 the filaments are almost white, in Type 17 the upper third is blue.

var. BENGALENSE.

Seeds brown, small. *Corolla* pale blue. *Stamens* anthers blue, filaments white. *Styles* white.

TYPE 19. Late, much branched, habit very erect, crowded and compact; average height 55 cm. *Foliage* light green. *Flowers*

medium sized, mediumly open; petals narrow, pale blue, a good deal of white at the base, markings very faint; styles white, stigmas white.

TYPE 20. Early, a medium amount of branching, habit open; average height 54 cm. *Foliage* bluish green. *Flowers* medium sized, mediumly open; petals broad, pale blue, darker in tone than in Type 19 but with less white at the base, markings more distinct; styles white, stigmas white.

These two types can be distinguished by the breadth of the petals which are narrow in Type 19, broad in Type 20.

var. AGRESTE.

Seeds brown, bold. *Corolla* pale blue. *Stamens* anthers blue, filaments white. *Styles* white.

TYPE 21. Very early, much branching both below and above, habit open but erect; average height 50 cm. *Foliage* somewhat light green. *Flowers* small, do not open fully; petals narrow, lavender coloured, markings very faint; styles and stigmatic surfaces white.

TYPE 22. Early to medium in maturity, a good deal of branching below, a great deal above, habit somewhat spreading; average height 46 cm. *Foliage* light green. *Flowers* medium in size, mediumly open; petals broad, pale blue but deeper in tone than in Type 21, markings faint but distinct; styles and stigmatic surfaces white.

In Type 21 the petals are narrow and lavender-coloured. In Type 22 broad and pale blue in colour.

var. MERIDIONALE.

Seeds brown, small. *Corolla* pale blue. *Stamens* anthers pale blue, filaments white. *Styles* very pale blue.

TYPE 23. Very late, much branched, habit erect, compact and crowded; average height 63 cm. *Foliage* dark green. *Flowers* medium in size, open, with a space between the narrow petals which are pale blue with distinct markings; styles very pale blue at the base only, stigmatic surfaces white.

var. GANGETICUM.

Seeds brown, small. *Corolla* pale blue. *Stamens* anthers blue, filaments pale blue. *Styles* blue.

TYPE 24. Late, a medium amount of branching, erect, crowded and compact; average height 57 cm. *Foliage* dark green. *Flowers* large, almost open; petals very narrow and curled at the edge, pale blue with practically no pink colour, markings distinct; filaments upper third pale blue; styles blue, stigmatic surfaces white.

var. LAXUM.

Seeds brown, medium in size. *Corolla* pale blue. *Stamens* anthers pale blue, filaments pale blue. *Styles* blue.

TYPE 25. Medium in maturity, a little branching below, a great deal above, habit spreading and open; average height 51 cm. *Foliage* bluish green. *Flowers* medium in size, mediumly open; petals narrow with spaces in between, very pale blue with a faint pink tinge, markings distinct but not prominent; filaments with a small amount of blue colour immediately below the anther; styles pale blue, stigmatic surfaces and tips white.

TYPE 26. Medium in maturity, a great deal of branching both above and below, habit spreading and open; average height 55 cm. *Foliage* light green. *Flowers* large, open, colour pale blue with a pink tinge but deeper in tone than in Type 25 and with more prominent markings, petals broad; filaments with a small amount of pale blue colour on one side at a little distance below the anthers; styles white with blue lines, stigmatic surfaces white, tips pink.

In Type 25 the petals are narrow and the styles pale blue, in Type 26 the petals are broad and the styles white with blue lines.

var. PRÆCOX.

Seeds brown, bold. *Corolla* pale blue. *Stamens* anthers faintly blue, filaments blue. *Styles* blue.

TYPE 27. Very early, a small amount of branching below, a great deal above, habit erect and open; average height 46 cm. *Foliage* light green. *Flowers* medium in size, open; petals broad, much deeper in tone than in Types 25 and 26, markings distinct; filaments upper third pale blue; anthers faintly blue; base of style pale blue, stigmatic surfaces white.

var. PRATENSE.

Seeds brown, small. *Corolla* blue. *Stamens* anthers white, filaments white. *Styles* blue.

TYPE 28. Late, a medium amount of branching, habit erect and somewhat compact; average height 71 cm. *Foliage* somewhat light green. *Flowers* small, mediumly open; petals narrow; styles blue, stigmatic surfaces white.

var. MINOR.

Seeds brown, small. *Corolla* blue. *Stamens* anthers white, filaments blue. *Styles* blue.

1. Styles pale blue, stigmatic surfaces white, petals broad.

TYPE 29. Late, a good deal of branching below, erect and compact in habit; average height 69 cm. *Foliage* somewhat light green. *Flowers* large and very open; petals broad; filaments upper half blue; styles pale blue, stigmatic surfaces white.

2. Styles blue, stigmatic surfaces white, petals broad.

TYPE 30. Late, much branching below, somewhat open in habit; average height 54 cm. *Foliage* dark green. *Flowers* large and open; petals broad; filaments upper third blue; styles blue, stigmatic surfaces white.

3. Styles blue, stigmatic surfaces pale purple, petals narrow.

TYPE 31. Early to medium in maturity, a fair amount of branching above, habit erect and compact; average height 62 cm. *Foliage* somewhat light green. *Flowers* small, half open; petals narrow somewhat deep blue, markings very distinct owing to a white patch at the base of the petals; filaments upper half blue; styles blue, stigmatic surfaces pale purple.

TYPE 32. Very late, a good deal of branching below, very erect and compact in habit; average height 63 cm. *Foliage* dark green. *Flowers* medium in size, mediumly open; petals narrow with much space in between; filaments with a small amount of blue colour just below the anther; styles blue, stigmatic surfaces pale purple.

Types 31 and 32 can be distinguished from one another by the amount of colour on the filaments.

var. HERBACEUM.

Seeds brown, bold. *Corolla* blue. *Stamens* anthers white, filaments blue. *Styles* blue.

TYPE 33. Early, a good deal of branching below, a great deal above, habit spreading and open; average height 49 cm. *Foliage* bluish green. *Flowers* medium in size, open; petals narrow with spaces in between; filaments upper third blue; styles blue at the base, stigmatic surfaces white tinged with pink.

var. PULCHRUM.

Seeds brown, small. *Corolla* blue. *Stamens* anthers blue, filaments white. *Styles* blue.

TYPE 34. Medium in maturity, a good deal of branching above, compact and erect in habit; average height 61 cm. *Foliage* dark green. *Flowers* large, open; petals broad, light blue in tone, markings distinct; anthers with some pale blue colour; styles blue, stigmatic surfaces purple.

var. CÆSIUM.

Seeds brown, medium in size. *Corolla* blue. *Stamens* anthers blue, filaments white. *Styles* blue.

TYPE 35. Late, much branching below, very spreading in habit; average height 48 cm. *Foliage* dark green. *Flowers* large, mediumly open; petals broad; styles blue, stigmatic surfaces white with pale purple tips.

var. BICOLOR.

Seeds brown, bold. *Corolla* blue. *Stamens* anthers blue, filaments white. *Styles* blue.

TYPE 36. Medium in maturity, a small amount of branching below, a great deal above, habit spreading and open; average height 46 cm. *Foliage* light green. *Flowers* small, do not open well; petals broad, somewhat light in tone; anthers very pale blue; styles tinged with pale blue, stigmatic surfaces white.

var. COMMUNE.

Seeds brown, small. *Corolla* blue. *Stamens* anthers blue, filaments blue. *Styles* blue.

1. Styles white with pale blue lines, stigmatic surfaces pale purple; petals narrow.

TYPE 37. Medium in maturity, a medium amount of branching above, somewhat spreading in habit; average height 63 cm. *Foliage* dark green. *Flowers* medium in size and do not open fully; petals narrow, somewhat dark blue in tone, markings very distinct; filaments with a trace of blue colour just below the anther; anthers pale blue; styles white with pale blue lines on the sides, stigmatic surfaces pale purple.

2. Styles pale blue, stigmatic surfaces white (sometimes tinged with pink or pale purple).

A. *Petals narrow.*

TYPE 38. Medium to late in maturity, erect but with an open habit, a moderate amount of branching above and below; average height 68 cm. *Foliage* dark green. *Flowers* medium in size, open with spaces between the petals which are narrow; filaments pale blue immediately below the anther; styles pale blue, stigmatic surface white with pink tips.

TYPE 39. Medium in maturity, a small amount of branching from the base, very open in habit; average height 56 cm. *Foliage* dark green. *Flowers* small, open; petals narrow with a good deal of space between; filaments bright blue immediately below the anther which is very pale blue; styles pale blue, stigmatic surfaces white with pink tips.

B. *Petals broad.*

(*a*) *Filaments with a small amount of blue just below the anther.*

a. Colour on the filaments in the form of a ring.

TYPE 40. Medium in maturity, a small amount of branching below, somewhat spreading in habit; average height 64 cm. *Foliage* somewhat blue green. *Flowers* large, open; petals broad; filaments with a small amount of bright blue colour immediately below the anther; styles pale blue, stigmatic surfaces white with pink tips.

TYPE 41. Very late, much branching below, very erect, crowded and compact; average height 62 cm. *Foliage* dark green. *Flowers* large, open; petals broad; filaments with small amount of bright blue colour just below the anther; styles pale blue, stigmatic surfaces white with pink tips.

TYPE 42. Medium in maturity, erect and somewhat compact in habit, a medium amount of branching below; average height 55 cm. *Foliage* somewhat dark bluish green. *Flowers* medium in size, do not open well; petals broad; filaments with a small amount of bright blue just below the anther; styles pale blue, stigmatic surfaces white.

Types 40 and 41 are tall, with large, open flowers. They differ in maturity. Type 42 is short with medium sized flowers which do not open well.

β. Colour only on one side of the filament.

TYPE 43. Medium to late in maturity, somewhat spreading in habit, a good deal of branching below; average height 56 cm. *Foliage* dark green. *Flowers* medium in size, do not open well; petals broad; filaments pale blue immediately below the anther but the colour is mostly on one side; styles pale blue, stigmatic surfaces white.

TYPE 44. Medium in maturity, a good deal of branching below, habit somewhat spreading and open; average height 49 cm. *Foliage* light green. *Flowers* large, open; petals broad; filaments bright blue immediately below the anther but the colour is mostly on one side; styles pale blue, stigmatic surfaces white with pink tips.

TYPE 45. Medium in maturity, very little branching below, habit somewhat open; average height 60 cm. *Foliage* bluish green. *Flowers* large, open; petals broad; filaments with a very small amount of deep blue colour immediately below the anther; styles pale blue, stigmatic surfaces and tips white.

In Type 43 the flowers are medium in size and do not open well while the colour on the filaments is pale; in Types 44 and 45 the flowers are large and open and the colour on the filaments is bright. These two types differ in height and habit.

(*b*) *Upper third of the filament bright blue.*

TYPE 46. Late, erect in habit but somewhat open at the base, a good deal of branching below; average height 61 cm. *Foliage* light green. *Flowers* very large, very open, with spaces between the petals; petals broad; filament upper third bright blue; styles pale blue, stigmatic surfaces white with pink tips.

TYPE 47. Medium in maturity, habit spreading at the base and open at the top, a fair amount of branching both above and below; average height 48 cm. *Foliage* somewhat light green. *Flowers* somewhat light in colour, large, open; petals broad; filaments upper third bright blue; styles pale blue, stigmatic surfaces white with pink tips.

TYPE 48. Late, a good deal of branching below, somewhat spreading; average height 60 cm. *Foliage* light green. *Flowers* large, mediumly open; petals broad; filaments upper third bright blue; styles pale blue, stigmatic surfaces white, tips pink.

These three differ in maturity and habit.

3. Styles blue, stigmatic surfaces white sometimes tinged with pink or pale purple.

A. *Petals broad, the colour on the filaments in the form of a ring immediately below the anther.*

TYPE 49. Medium in maturity, a medium amount of branching below, erect in habit; average height 64 cm. *Foliage* bluish green. *Flowers* large, open; petals broad; filaments with a small amount of blue just below the anther; anthers pale blue; styles blue, stigmatic surfaces white with pink tips.

TYPE 50. Late, a good deal of branching below, erect and crowded in habit; average height 51 cm. *Foliage* light green. *Flowers* large, open; petals broad; filaments blue just below the anther; styles blue, stigmatic surfaces and tips white.

TYPE 51. Late, a great deal of branching below, erect, crowded and compact in habit; average height 47 cm. *Foliage* light green. *Flowers* small, do not open fully, petals broad; filaments with a small amount of dark blue colour immediately below the anther; styles blue, stigmatic surfaces and tips white.

In Type 51 the flowers are small and half closed whereas in Types 49 and 50 they are large and open. These two types differ in maturity and habit.

B. *Petals broad, upper third of filaments blue.*

TYPE 52. Late, very little branching below, habit very open; average height 67 cm. *Foliage* dark green. *Flowers* large, not very open; petals broad; filaments upper third bright blue; styles blue, stigmatic surfaces white.

TYPE 53. Very late, a medium amount of branching below, habit erect; average height 60 cm. *Foliage* light green. *Flowers* large, open, light in tone; petals broad with spaces in between; filaments upper third blue; anthers faintly blue; styles a decided blue, stigmatic surfaces white.

TYPE 54. Medium in maturity, a fair amount of branching above, erect and compact in habit; average height 59 cm. *Foliage* somewhat dark bluish green. *Flowers* medium in size, mediumly open; petals broad; filaments upper third blue but on one side only; styles blue, stigmatic surfaces white and tips pink.

In Type 52 the anthers are bright blue, in Types 53 and 54 pale blue. Type 53 is late with open flowers, Type 54 medium in maturity with flowers which do not open well,

C. *Petals broad, upper half of filaments purplish blue, corolla purple in tone.*

TYPE 55. Medium in maturity, much branching both above and below, habit spreading and open; average height 48 cm. *Foliage* dark green. *Flowers* medium in size, almost open; petals broad, purple in tone; filaments upper half purplish blue; anthers pale blue; stigmatic surfaces and tips white.

D. *Petals broad, upper half of filaments blue.*

TYPE 56. Very early, a good deal of branching below, mediumly open in habit; average height 47 cm. *Foliage* bluish green. *Flowers* medium in size and mediumly open; petals narrow; filaments upper half blue, anthers pale blue; styles blue, stigmatic surfaces and tips white.

4. Styles blue, stigmatic surfaces purple.

A. *Petals narrow, a very small amount of blue colour on the filaments below the anther.*

TYPE 57. Very late, a good deal of branching from the base, upper branches crowded and compact, very erect in habit; average height 57 cm. *Foliage* dark green. *Flowers* medium in size, open, with a space between the petals which are narrow; filaments with a small amount of pale blue just below the anther; styles bright blue, stigmatic surfaces purple.

TYPE 58. Very late, a great deal of branching from the base, habit erect, mediumly compact; average height 51 cm. *Foliage* dark green. *Flowers* small, do not open well; petals narrow, with spaces in between; filaments with a small amount of bright blue colour just below the anther; styles blue, stigmatic surfaces purple.

TYPE 59. Medium in maturity, a small amount of basal branching, erect in habit; average height 70 cm. *Foliage* light green. *Flowers* medium in size and mediumly open; petals narrow; filaments with a small amount of bright blue colour just below the anther; styles blue, stigmatic surfaces purple, somewhat paler than in the rest of this class.

In Type 57 the colour on the filaments is pale blue, in Types 58 and 59 bright blue. These two types differ in the size of the flower and in the tone of colour of the stigmatic surfaces.

B. *Petals narrow, upper third of the filaments bright blue.*

TYPE 60. Late, erect, a great deal of branching both above and below, compact, crowded and erect in habit; average height 55 cm.

Foliage somewhat light green. *Flowers* small, do not open well, somewhat deep blue in tone; petals narrow; filaments upper third bright blue; anthers bright blue; styles bright blue, stigmatic surfaces purple.

C. *Petals narrow, filaments with a small amount of purple just below the anthers.*

TYPE 61. Very early, erect, habit open; average height 51 cm. *Foliage* light green. *Flowers* small and mediumly open with a space between the petals which are narrow; filaments with a small amount of purple or very deep blue just below the anther; styles blue, stigmatic surfaces purple.

D. *Petals narrow, upper third of the filaments purple.*

TYPE 62. Late, a good deal of branching from the base, very erect, crowded and compact; average height 62 cm. *Foliage* dark green. *Flowers* medium in size, open; petals narrow with small spaces in between; filaments upper third purple or very deep blue; anthers pale blue; styles blue, stigmatic surfaces purple.

var. CAMPESTRE.

Seeds brown, medium in size. *Corolla* blue. *Stamens* anthers blue, filaments blue. *Styles* blue.

1. Styles pale blue, stigmas white sometimes tinged with pink.

A. *Corolla somewhat purple in tone.*

TYPE 63. Early, a small amount of branching below, a great deal above, habit erect, crowded and compact; average height 54 cm. *Foliage* dark green. *Flowers* medium in size, open; petals broad, purple in tone; filaments upper third purplish blue; styles pale blue, stigmatic surfaces white.

B. *Corolla normal blue.*

(*a*) *Early or very early, short, habit spreading.*

TYPE 64. Very early, somewhat open and spreading in habit, a little branching below, a great deal above; average height 49 cm. *Foliage* bluish green. *Flowers* medium in size, open; filaments upper fourth purplish blue; styles pale blue at the base, stigmatic surfaces white.

TYPE 65. Early, a small amount of branching below, a great deal above, habit spreading and open; average height 50 cm. *Foliage* bluish green. *Flowers* small, open; petals somewhat narrow with spaces in between; filaments upper third pale blue, most of the

colour on one side; styles pale blue at the base, white above stigmatic surfaces white with pink tips.

Type 66. Early, a very small amount of branching below, a great deal above, habit open; average height 48 cm. *Foliage* bluish green. *Flowers* medium in size, but larger than in Type 64, open; petals broad; filaments upper fourth blue; styles pale blue, stigmatic surfaces white.

These types differ in the size of their flowers and in the amount of colour on the filaments.

(*b*) *Medium in maturity, short, erect, with an open top.*

Type 67. Medium in maturity, a great deal of branching both above and below, habit erect with an open top; average height 48 cm. *Foliage* light green. *Flowers* medium in size, open, petals somewhat narrow with small spaces in between; filaments upper half pale blue; styles pale blue, stigmatic surfaces white with pink tips.

(*c*) *Late, tall, erect and compact in habit.*

Type 68. Late, a fair amount of branching below, very erect and compact in habit; average height 71 cm. *Foliage* somewhat light green. *Flowers* small, half closed; petals broad, blue in tone; filaments with a small amount of bright blue colour immediately below the anther; anthers bright blue; styles pale blue, stigmatic surfaces white.

Type 69. Late, some branching below, upright and compact in habit; average height 64 cm. *Foliage* dark green. *Flowers* medium to large, open; petals broad; filaments with a small amount of blue colour immediately below the anther; styles pale blue, stigmatic surfaces white.

These two types differ in the size of the flower and in height.

2. Styles blue (less pale than in 1), stigmatic surfaces pale purple.

A. *Petals narrow.*

Type 70. Medium in maturity, a good deal of branching both above and below, habit spreading with an open top; average height 49 cm. *Foliage* dark green. *Flowers* small, half closed; petals narrow with spaces in between; filaments upper third blue; anthers bright blue; styles blue, stigmatic surfaces white with pale purple tips.

Type 71. Medium in maturity, a great deal of branching both above and below, habit somewhat spreading and open; average height

45 cm. *Foliage* dark green. *Flowers* medium in size, open; petals somewhat deep blue in colour; narrow with spaces in between; filaments upper half blue; anthers pale blue; styles blue, stigmatic surfaces white with pale purple tips.

These two types differ in the size of their flowers and in the tone of colour of the anthers.

B. *Petals broad.*

TYPE 72. Late, a medium amount of branching below, habit spreading; average height 49 cm. *Foliage* dark green. *Flowers* large, open; petals broad with spaces in between; filaments upper third pale blue; styles blue, stigmatic surfaces white with pale purple tips.

TYPE 73. Late, much branching both below and above, habit somewhat spreading and open; average height 52 cm. *Foliage* somewhat light green. *Flowers* large, open; petals broad; filaments upper third bright blue; styles blue, stigmatic surfaces white with pale purple tips.

TYPE 74. Medium in maturity, much branching both below and above, habit spreading and open; average height 54 cm. *Foliage* bluish green. *Flowers* medium in size, mediumly open; petals broad; filaments upper third blue; styles blue, stigmatic surfaces white, tips pale purple.

Types 67 and 73 are late with large, open flowers. They differ in the tone of colour on the filaments. Type 74 is medium in maturity with medium sized flowers.

3. Styles blue, stigmatic surfaces purple.

A. *Petals narrow.*

TYPE 75. Medium in maturity, much branching both above and below, habit spreading with an open top; average height 53 cm. *Foliage* dark green. *Flowers* medium in size, open; petals narrow with spaces in between; filaments upper third pale blue; anthers pale blue; styles blue, stigmatic surfaces purple.

TYPE 76. Early, a small amount of branching below, a great deal above, habit erect, crowded and somewhat compact; average height 62 cm. *Foliage* bluish green. *Flowers* small, half open; petals very narrow with spaces in between, markings very prominent; filaments with a small amount of blue colour on one side immediately below the anther; styles blue, stigmatic surfaces and tips purple.

These two types differ in the size of the flowers and the amount of colour on the filaments.

B. *Petals intermediate in breadth.*

TYPE 77. Late, much branching both above and below, habit somewhat spreading and open; average height 54 cm. *Foliage* dark green. *Flowers* medium in size, almost open; petals somewhat narrow; filaments upper third purplish blue; anthers bright blue; styles blue, stigmatic surfaces and tips purple.

C. *Petals broad.*

TYPE 78. Medium in maturity, much branching both above and below, habit spreading and open; average height 50 cm. *Foliage* bluish green. *Flowers* medium in size, open; petals broad; filaments upper third pale blue; styles blue, stigmatic surfaces pale purple.

4. Styles bright blue, stigmatic surfaces bright purple, petals narrow.

TYPE 79. Early, much branching both below and above, habit somewhat spreading below, crowded above; average height 54 cm. *Foliage* dark green. *Flowers* small, mediumly open; petals narrow with wide spaces in between; filaments upper third bright blue; anthers bright blue; styles bright blue, stigmatic surfaces and tips bright purple.

5. Styles purplish blue, stigmatic surfaces pale purple, petals broad.

TYPE 80. Late, a little branching below, habit spreading and open; average height 60 cm. *Foliage* somewhat dark green. *Flowers* large, open; petals broad; filaments blue but the colour is mostly on one side; styles purplish blue, stigmatic surfaces pale purple.

var. VULGATUM.

Seeds brown, bold. *Corolla* blue. *Stamens* anthers blue, filaments blue. *Styles* blue.

1. Styles pale blue below, stigmatic surfaces white.

A. *Petals narrow.*

TYPE 81. Early, a small amount of branching below, a great deal above, habit erect but open; average height 45 cm. *Foliage* light green. *Flowers* small, mediumly open; the petals which are almost broad have no spaces in between, corolla light in tone; a trace of blue on the filaments; anthers faintly blue; styles very pale blue at the base, stigmatic surfaces white.

TYPE 82. Medium in maturity, a small amount of branching below, a great deal above, habit spreading and open ; average height 47 cm. *Foliage* dark green. *Flowers* small, open ; petals narrow, pale in tone ; filaments with a small amount of very pale blue colour immediately below the anther ; anthers very pale blue ; styles very pale blue, stigmatic surfaces white.

TYPE 83. Medium in maturity, much branching below, habit spreading and open ; average height 47 cm. *Foliage* light green. *Flowers* small, open ; petals somewhat narrow with small spaces in between ; filaments upper fourth blue ; styles pale blue at the base, stigmatic surfaces white.

TYPE 84. Early, a moderate amount of branching below, a great deal above, habit somewhat spreading ; average height 50 cm. *Foliage* somewhat light green. *Flowers* small, do not open fully ; petals somewhat narrow ; filaments upper third blue ; styles pale blue, stigmatic surfaces white.

There is only a trace of blue colour on the filaments in Types 81 and 82 which differ from one another in the time of maturity and in habit. In Type 83 the upper fourth of the filament is blue and the flowers are open, in Type 84 the upper third of the filament is blue and the flowers are half closed.

B. *Petals broad.*

TYPE 85. Very early, a very small amount of branching below, a great deal above, habit somewhat open ; average height 51 cm. *Foliage* bluish green. *Flowers* medium in size, open ; petals intermediate in breadth ; filaments with a small amount of blue colour immediately below the anther ; styles pale blue, stigmatic surfaces white.

TYPE 86. Early, habit somewhat open, a small amount of branching below, a good deal above ; average height 41 cm. *Foliage* light green. *Flowers* medium in size, half closed, corolla light in tone ; petals broad ; filaments upper half blue ; anthers pale blue ; styles pale blue at the base, stigmatic surfaces white.

TYPE 87. Early, a small amount of branching below, a great deal above, habit spreading and open ; average height 48 cm. *Foliage* dark green. *Flowers* medium in size, open ; petals broad ; filaments upper third deep blue ; anthers bright blue ; styles pale blue, stigmatic surfaces white.

TYPE 88. Medium in maturity, a small amount of branching below, a great deal above, habit spreading and open ; average height 52 cm.

Foliage dark green. *Flowers* large, open; petals broad; filaments upper half deep purple; anthers bright blue; styles pale blue below, stigmatic surfaces white.

These four types differ in the amount and tone of the colour on the filaments.

2. Styles completely blue, stigmatic surfaces white, sometimes tinged with pink or pale purple.

A. *Petals narrow.*

TYPE 89. Early, a small amount of branching below, a great deal above, habit spreading and open; average height 56 cm. *Foliage* dark green. *Flowers* small, open; petals very narrow with wide spaces in between, markings prominent owing to a white patch at the base of each petal; filaments with a small amount of blue colour just below the anther on one side only; styles blue; stigmatic surfaces white tinged with pink.

TYPE 90. Medium in maturity, a moderate amount of branching, upright but open in habit; average height 49 cm. *Foliage* light green. *Flowers* small, do not open well; petals narrow with spaces in between; filaments with a very small amount of bright blue colour immediately below the anther; anthers pale blue; styles blue, stigmatic surfaces white with a purple tinge.

TYPE 91. Early, a good deal of branching below, a great deal above, habit somewhat spreading and open; average height 46 cm. *Foliage* light green. *Flowers* medium in size, open; petals narrow; filaments upper half purplish blue; styles blue, stigmatic surfaces white tinged with pink.

TYPE 92. Early, a small amount of branching, spreading and open in habit; average height 47 cm. *Foliage* bluish green. *Flowers* medium in size, open; petals very narrow with much space in between, markings prominent owing to a white patch at the base; filaments upper third blue; styles blue, stigmas white tinged with pink.

TYPE 93. Medium in maturity, a very small amount of branching below, a great deal above, habit spreading and open; average height 46 cm. *Foliage* dark green. *Flowers* small, open; petals narrow with spaces in between, somewhat light in colour; filaments upper third blue; anthers a paler blue than in Type 92; styles blue, stigmas white tinged with pink.

These types differ from one another in the amount of colour on the filament. In both Types 89 and 90 this is very small, but in Type 89 it is found on one side only, whereas in Type 90 it occurs in the form of a ring. In Type 91 the upper third of the filament is purplish blue while in Types 92 and 93 the upper third is blue. These two types differ in maturity and in the tone of colour of the anthers.

B. *Petals broad.*

(*a*) *Upper third of the filaments blue.*

TYPE 94. Medium in maturity, a very small amount of branching below, a great deal above, habit spreading and open ; average height 48 cm. *Foliage* bluish green. *Flowers* large, open ; petals broad with spaces in between ; filaments upper third blue ; styles blue, stigmatic surfaces white, tips pink.

TYPE 95. Early, a small amount of branching at the base, habit spreading and open ; average height 56 cm. *Foliage* dark green. *Flowers* large, open ; petals broad ; filaments upper third blue ; styles blue, stigmatic surfaces white, tips pink.

TYPE 96. Medium in maturity, much branching at the top, a small amount below, habit crowded at top, somewhat spreading below ; average height 54 cm. *Foliage* somewhat light green. *Flowers* large, open ; petals broad ; filaments upper third blue ; styles blue, stigmatic surface white, tips pink.

In these three types the flowers are large and open. They differ in the time of maturity and in the colour of the foliage.

TYPE 97. Medium in maturity, very little branching at the base, a little but not much at the top, habit erect with an open top ; average height 63 cm. *Foliage* dark green. *Flowers* medium in size, open ; petals broad ; filaments upper fourth blue ; styles blue, stigmatic surfaces white, tips pink.

TYPE 98. Medium in maturity, a good deal of branching below, a great deal above, habit somewhat spreading with an open top ; average height 53 cm. *Foliage* dark green. *Flowers* medium in size, open ; petals broad ; filaments upper third blue ; styles blue, stigmatic surfaces white, tips pink or pale purple.

TYPE 99. Early, a small amount of branching below, a great deal above, habit erect with an open top ; average height 60 cm. *Foliage* light green. *Flowers* medium in size, mediumly open ; petals broad ; filaments upper third blue ; styles pale blue, stigmatic surfaces white, tips pink or pale purple.

TYPE 100. Medium in maturity, a small amount of branching below and a good deal above, habit spreading and open ; average height 49 cm. *Foliage* somewhat light green. *Flowers* medium in size, open ; petals broad ; filaments upper third blue ; styles light blue, stigmatic surfaces white tinged with purple.

In these four types the flowers are medium in size. They differ in height and in the time of maturity.

TYPE 101. Early, a fair amount of branching below, much branching at the top, habit somewhat open ; average height 56 cm. *Foliage* light green. *Flowers* small, half open ; petals broad ; filaments upper third blue ; styles blue, stigmatic surfaces white with pink tips.

In this type the flowers are small.

(*b*) *Filaments upper third purple, corolla very deep blue.*

TYPE 102. Very early, a small amount of branching from the base, erect and somewhat open in habit ; average height 56 cm. *Foliage* light green. *Flowers* medium in size, mediumly open ; petals broad, very deep blue ; filaments upper third deep purple ; anthers bright blue ; styles pale violet, stigmatic surfaces white, tips pink.

TYPE 103. Medium in maturity, a little branching at the base, a great deal above, habit spreading with an open top, average height 56 cm. *Foliage* dark green. *Flowers* large, open ; petals somewhat deep blue, broad ; filaments upper third purple ; anthers very pale blue ; styles bluish violet, stigmas white tinged with pink.

These two types differ in the time of maturity, in habit and in the size of their flowers.

3. Styles blue, stigmatic surfaces purple.

A. *Filaments with a small amount of colour generally on one side only.*

TYPE 104. Early, a small amount of branching below, a great deal above, habit upright but open ; average height 55 cm. *Foliage* dark green. *Flowers* small, half closed ; petals narrow with large spaces in between, the petals being folded in the centre ; filaments with a small amount of blue colour immediately below the anther ; styles blue, stigmatic surfaces and tips purple.

TYPE 105. Late, a small amount of branching below, a great deal above, habit spreading and open ; average height 54 cm. *Foliage* dark green. *Flowers* large, open ; petals very narrow, markings

prominent owing to the white base ; filaments upper fourth purplish blue immediately below the anther; styles blue, stigmatic surfaces pale purple.

Type 106. Early, much branching below and above, habit spreading and open; average height 41 cm. *Foliage* dark green. *Flowers* small, open; some space between the petals which are almost broad; filaments with a small amount of blue colour immediately below the anther; anthers very pale blue; styles blue, stigmatic surfaces purple.

Type 107. Late, a small amount of branching below, a great deal above, habit spreading and open; average height 50 cm. *Foliage* dark green. *Flowers* medium in size, open; petals narrow with large spaces in between; filaments with a small amount of blue colour immediately below the anther; anthers pale blue; styles blue, stigmatic surfaces purple.

These four types differ in the time of maturity and in the size of their flowers.

B. *Upper third of the filaments blue, the colour in the form of a ring.*

Type 108. Very early, very little branching either at the base or above, habit erect with an open top; average height 57 cm. *Foliage* bluish green. *Flowers* small, half open; petals somewhat narrow but still belonging to the broad class; filaments upper half purple; anthers blue; styles blue, stigmatic surfaces purple.

Type 109. Early, a medium amount of branching, habit open and spreading; average height 47 cm. *Foliage* somewhat light green. *Flowers* small, mediumly open; petals narrow with spaces in between; filaments upper third blue; styles blue, stigmatic surfaces pale purple.

Type 110. Medium in maturity, a small amount of branching below, a great deal above, habit spreading and open; average height 41 cm. *Foliage* dark green. *Flowers* small, open, with spaces between the petals which are narrow; filaments upper third purplish blue; anthers pale blue; styles blue, stigmas purple.

Type 111. Medium in maturity, a good deal of branching, habit crowded but open; average height 45 cm. *Foliage* dark green. *Flowers* small to medium in size and mediumly open; petals narrow; filaments upper third blue; anthers pale blue; styles blue, stigmatic surfaces bright purple.

In these four types the flowers are small and not very open with narrow petals. They differ in the time of maturity and in height.

TYPE 112. Very early, branching sparse, habit open; average height 45 cm. *Foliage* dark green. *Flowers* medium in size, open; petals narrow with spaces in between; filaments upper third blue; styles blue, stigmatic surfaces bright purple.

TYPE 113. Early, habit erect and crowded, a small amount of branching below, a great deal above; average height 55 cm. *Foliage* light green. *Flowers* medium in size, almost open; petals broad, pale blue; filaments upper third purplish blue; styles blue, stigmatic surfaces purple.

TYPE 114. Medium in maturity, a small amount of branching below, a great deal above, habit spreading and open; average height 52 cm. *Foliage* dark green. *Flowers* medium in size, open; petals narrow with large spaces in between, markings very prominent owing to the white base of the petal; filaments upper third blue; styles blue, stigmatic surfaces bright purple.

TYPE 115. Medium in maturity, a small amount of branching below, a great deal above, habit erect but open; average height 49 cm. *Foliage* light green. *Flowers* medium in size, open, some space between the petals which are narrow; filaments upper third purplish blue; styles blue, stigmas purple.

TYPE 116. Late, a good deal of branching, habit crowded but somewhat open; average height 50 cm. *Foliage* somewhat light green. *Flowers* medium in size, almost open; petals narrow with spaces in between; filaments upper third blue; anthers very pale blue; styles blue, stigmatic surfaces bright purple.

4. Styles purple, stigmatic surfaces white with purple tips.

TYPE 117. Early, a small amount of branching below, a great deal above, habit spreading and open; average height 45 cm. *Foliage* light green. *Flowers* medium in size, open; petals narrow with spaces in between; filaments upper half purple; styles purple, stigmatic surfaces white, tips purple.

var. TINCTORIUM.

Seeds brown, bold. *Corolla* purple. *Stamens* anthers blue, filaments blue. *Styles* blue.

TYPE 118. Very early, a fair amount of branching both below and above, habit somewhat spreading and open; average height 44 cm.

Foliage dark green. *Flowers* small, do not open fully; petals very narrow, edges incurved, colour bluish purple; filaments upper third purplish blue; anthers pale blue; styles pale blue below, violet above, stigmatic surfaces white tinged with pink.

TYPE 119. Very early, a fair amount of branching both below and above, habit somewhat spreading and open; average height 49 cm. *Foliage* light green. *Flowers* small, do not open fully; petals broad, almost pink, markings dark blue and very prominent; filaments upper third pale blue; styles pale blue at the base, stigmas white.

TYPE 120. Medium in maturity, a fair amount of branching both below and above, habit somewhat spreading and open; average height 50 cm. *Foliage* somewhat dark green. *Flowers* medium in size, do not open well, colour a bluish purple; petals broad; filaments upper third purple; anthers pale blue; styles pale blue at the base, stigmas white.

In Type 118 the petals are narrow whereas they are broad in Types 119 and 120. These two types are easily distinguished by the colour of their corolla.

var. SATIVUM.

Seeds brown, small. *Corolla* violet. *Stamens* anthers blue, filaments blue. *Styles* blue.

TYPE 121. Medium in maturity, much branching both above and below, habit erect, crowded and compact; average height 52 cm. *Foliage* dark green. *Flowers* large, open, resemble the normal blue in depth of colour except that they are violet not blue; petals broad; filaments upper third purplish blue; anthers very pale blue; styles pale blue, stigmatic surfaces white.

TYPE 122. Early to medium in maturity, a small amount of branching below, a great deal above, habit spreading and open; average height 57 cm. *Foliage* light green. *Flowers* large, open, colour pinker in tone than in Types 121 and 123; petals broad; filaments pale violet; anthers bright blue; styles pale violet blue with deep blue lines on the sides, stigmatic surfaces pale violet.

TYPE 123. Early, a small amount of branching below, a great deal above, habit spreading and open; average height 50 cm. *Foliage* bluish green. *Flowers* medium in size and mediumly open; petals narrow with small spaces in between, resembling Type 121 in colour but slightly darker; filaments upper third purple on one

side only; anthers very pale blue; styles pale blue, stigmatic surfaces white.

Type 123 can be distinguished from the other two by the narrowness of its petals. Type 121 differs from Type 122 in the tone of colour of the filaments, anthers and styles.

V. THE ECONOMIC ASPECT.

The commercial classification of Indian linseed is based on the size and colour of the seed. Three sizes are recognized—bold, medium and small—and two colours are distinguished—yellow and brown. Other things being equal, the larger seeds fetch a higher price. As would be expected, these differences in price depend largely on oil content. This is clear from the percentages of oil (ether extract) in the various types (Table VIII). The determinations were made from samples grown at Pusa in 1919 where the soil conditions favoured the small brown types.

TABLE VIII.

Oil content and size of seed.[1]

Type No.	Size and colour of seed	Percentage of oil (ether extract)	
1 2 3	Bold yellow	41·85 42·69 41·93	mean 42·15
6 7 80	Bold fawn	43·95 43·31 44·76	„ 44·01
84 103	Bold brown	42·32 44·36	„ 43·81
68 72	Medium brown	38·91 39·38	„ 39·15
12 19 20 28 29 32 121	Small brown	36·18 37·20 40·07 35·12 37·80 37·19 39·00	„ 37·51

It will be evident from the above table that there is a certain amount of correlation between the size of the seed and the oil content. This is probably due to the greater percentage of husk in the smaller seeded varieties. There

[1] Previous determinations of the oil content have been carried out on mixed samples and are, therefore, not very significant.

are also differences between the individual types in any one group but these are insignificant compared with that between the bold and small seeded varieties. To obtain a high oil content, the cultivation of a large seeded type would appear essential.

As regards the colour, it is sometimes stated that the pale seeded varieties are the most valuable.[1] It is possible that this belief has partly arisen from the fact that all the yellow varieties have bold seeds and are therefore rich in oil content. The following letter from Messrs. Ralli Brothers, dated Bombay, 17th March, 1919, makes the position clear as regards the relative value of the brown and yellow colour for the export trade.

"With reference to the conversation we have had some time ago, on the above subject, we are informed by our Home Firms that crushers in the south of France pay particular attention to edible oils, and as a mixture of yellow seeds up to 25 per cent. in brown linseed gives a finer quality of oil and moreover a higher proportion of edible oil, buyers show a marked preference for such qualities.

The same, however, is not the case with buyers of the north of France and in the United Kingdom where they like better brown seeds, with no admixture of yellow seeds, the latter rendering the sale of the cake difficult, by discolouring it. A high admixture of yellow seeds, would also be objected to in Marseilles, for the same reason."

The economic value of any variety of linseed depends, however, not only on the percentage of oil in the seed but also on the yield of seed obtained per acre and of the two this latter factor is the more important. High yields of seed are only obtained if the variety is suited to the soil and climatic conditions of the locality. It is generally found that this depends almost entirely on the suitability of the root system to its environment. The only other morphological character which appears to be important from the economic point of view is the power of branching. As has been seen on page 142, the number of basal branches varies very much with the soil conditions, but, in addition to this, the power of forming numerous branches is a distinct inherited varietal character. This is true both of the primary branching from the base and the secondary branching above. In 1921, when grown under exactly comparable conditions, the average number of branches per plant varied from two to fourteen among the 121 types. In choosing a variety for distribution, it is essential to choose one of which the potential branching power is large.

[1] Duthie, J. F. and Fuller, J. B. in *Field and Garden Crops of the North Western Provinces and Oudh*, 1883, Part II, p. 41, state that oil of the "white seeded" variety is in many respects more valuable than that of the ordinary linseed especially for colour mixing.

Another character which is important from the point of view of seed distribution, although it does not directly affect the yield, is the colour of the corolla. In most districts, the local linseed is blue flowered. It is extremely difficult to distinguish one blue flowered variety from another. The F_1 between two blue corollas is usually blue also. Thus if the improved variety has a blue corolla it is practically impossible to check the extent of the distribution and the purity of the crops. A white, purple or lilac coloured corolla is, therefore, a distinct asset in an improved variety.

As regards the introduction of improved varieties, it has been found that all the types with *bold* seed (*i.e.*, a high percentage of oil) belong to Peninsular India and will not thrive on the alluvium, except possibly in the Punjab. As was mentioned on page 138, this is due to the fact that all these types so far obtained have a deep root system. Seed of the bold seeded types isolated during this investigation has, therefore, been sent to the Department of Agriculture of the Central Provinces for trial. Some of them were said in 1922 to be distinctly promising and further trials will probably indicate more definitely which of these types are suitable for distribution. It is also hoped to carry out trials of these bold seeded types in other localities of the black cotton soil area.

As regards the alluvium, variety trials have been carried out during the last three years at Pusa with some of the more promising types. Three types (12, 29 and 121) have consistently emerged as definitely superior to the local variety. Of these improved kinds, Type 29 is blue flowered, Type 121 purple flowered and Type 12 white flowered. In 1923, Types 121 and 12 in a series of very careful tests gave a yield 40 to 50 per cent. above that of the local variety. The actual yields per acre on the most reliable series of plots was :—

Type 121	..	..	..	$11\frac{1}{2}$ maunds per acre.
Type 12	..	..	..	$11\frac{1}{2}$ maunds per acre.
Local	..	..	..	$7\frac{1}{2}$ maunds per acre.

These yields are so very promising that seed of both Types 12 and 121 have been distributed for trial to the Provincial Departments of Agriculture and others. Type 29, though giving yields as high as Types 121 and 12, suffers in Bihar from the disadvantage of secondary flowering. It is therefore only suitable for localities with a longer growth period than Bihar and has been sent to the Punjab for trial. Further tests with other types are in progress at Pusa, but the success of the preliminary trials leaves no doubt that the yield of linseed on the alluvium can be very considerably increased by the systematic distribution of these improved kinds.

Experiments are also in progress to see whether it is possible to produce by hybridization a bold seeded variety suitable for the United Provinces and Bihar which will give a high yield of seed. It will be interesting to see whether such a combination is possible. The fact that none of the bold seeded types, isolated by selection, are at all suitable is against it, as is also the observation that the large seeded varieties of almost all crops—*khesari* (*Lathyrus sativus*), lentils (*Ervum lens*), etc., generally belong to the black cotton soil areas whereas, in Bihar, the corresponding varieties have very small seeds. There is, however, one striking exception to this rule. Although the local varieties of wheat are particularly small grained, it has been possible to obtain a very large seeded wheat, Pusa 4, which is well suited to certain tracts of the alluvium and gives a high yield. As, however, such a variety of linseed will have to be created by hybridization, it will take several years before the desired result can be achieved.

CONTENTS

LIST OF ILLUSTRATIONS

Plates

Text Figures

STUDIES IN GUJARAT COTTONS, PART II.

BY

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IN the author's former Memoir on Gujarat cottons[1] he described the various types of cotton which are grown in that part of Western India, and gave a detailed description of the variety known as *goghari* which forms one of the three main types of *Gossypium herbaceum* cultivated in Gujarat, which is characterised in all its strains by roughness, shortness of staple, and high ginning percentage. The present Memoir deals essentially with the second of the great varieties of *Gossypium herbaceum* of Gujarat, namely, that known as *broach deshi*, or *lalio*, together with a critical consideration of the environment, chiefly climatic, of the cotton plant in Gujarat, and also with a number of other observations on the general botanical characteristics of *Gossypium herbaceum* cottons.

I. THE ENVIRONMENT OF COTTON IN SOUTH GUJARAT.

Gujarat consists essentially of a flat plain lying almost at sea level, and stretching between the sea and various mountain ranges, from a hundred miles north of Bombay, northward to the fringe of the Rajputana desert. In the present description the conditions are considered which prevail in South Gujarat, of which Surat may be taken as the most typical centre, and which differ in a very marked manner both in climate and soil from the regions north of Baroda.

The general aspect of this South Gujarat region, and especially of the portion—from within five miles of the sea to twenty miles inland—where cotton is chiefly grown, is that of a flat plain formed by the alluvium deposited in the basins of the Tapti and the Nerbudda rivers. The soil, being derived from the region of the Deccan trap, has all the characteristics of the black cotton soil or

[1] Studies in Gujarat Cottons, Part I, *Mem. Dept. of Agri. India, Bot. Ser.*, Vol. XI. No. 4, 1921.

regur of Western India, varying in depth and in stiffness, however, considerably from place to place.

This black soil possesses in this region in a pre-eminent degree the power of expansion and contraction on wetting and drying respectively, which is the most obvious character of black cotton soil. As a result, in the hot weather, it is traversed by deep and wide cracks which disappear with the first advent of the rains. The cracking of the soil is considered by the people to be a great advantage, as it leads to the surface soil being mixed with the subsoil either during the process of cultivation or during the first rains. The flow of the water into the cracks carrying with it a large amount of surface soil leads on the one hand to a capacity on the part of the soil to absorb a very large amount of rain—even up to seven or eight inches—in one continuous fall, without surface wash or erosion, and to the conversion of a field into a series of basins, specially if the previous crop be a deep-rooted one, which needs to be levelled up before any further operation is undertaken. Though the soil at the first monsoon rain is capable of absorbing an enormous amount of water, once the cracks are filled up and the soil saturated, the water drains away so slowly, that it can only absorb further water with difficulty, and if the rain remains continuous and heavy, erosion takes place, water stagnates on the surface and all the signs of temporary water-logging are seen.

The following analysis of typical cotton growing soils from two centres in the tract in question will indicate some of the characteristics which are found. The surface soil is from the surface to eight inches deep; the subsoil represents the next eight inch layer.

	Surat		Navsari	
	Surface soil	Subsoil	Surface soil	Subsoil
MECHANICAL ANALYSIS	Per cent.	Per cent.	Per cent.	Per cent.
Sand (particles over 0·032 mm. diameter) ..	26·0	23·3	32·9	34·2
Fine sand (particles 0·016 to 0·032 mm.) ..	33·0	31·0	23·8	24·9
Coarse silt (particles 0·006 to 0·016 mm.) ..	17·3	20·0	18·9	18·2
Medium silt (particles 0·004 to 0·006 mm.) ..	12·6	13·9	12·6	11·8
Fine silt (particles 0·002 to 0·004 mm.) ..	6·6	6·3	7·4	6·0
Clay (particles under 0·002 mm.) ..	3·6	4·6	4·4	4·9
CHEMICAL ANALYSIS				
Organic matter and combined water ..	6·0600	5·4600	6·0900	5·8100
Lime (CaO)	2·5700	2·5300	1·4400	1·6800
Combined carbon dioxide	0·1700	0·1600	0·0500	0·0500
Available potash (K_2O)	0·0074	0·0031	0·0071	0·0070
Available phosphoric acid (P_2O_5)	0·0070	0·0030	0·0066	0·0044

The mechanical analysis hardly illustrates the real character of these soils. It, however, shows them as essentially coarse grained soil, their clayey and plastic character being due to a large proportion of actual colloid material which an ordinary mechanical analysis is not able to show. From the chemical point of view the soil contains much lime extractable by hydrochloric acid, but very little of it in the form of carbonate. The available potash and phosphoric acid, as determined by Dyer's method, is about normal for this class of soils in the tropics.

The soils which have been described are typical of the real centre of the cultivation of *broach deshi* cotton in South Gujarat, and the centres in which this cultivation is most highly developed, are actually in the Surat District. North of this, even in the Broach District itself, the purity of the cotton grown rapidly declines and the production is chiefly a mixture of *broach deshi* and *goghari* cotton. In this area the soil also changes in character, becomes much lighter in agricultural character, and ultimately, as one goes further north, is replaced by a typical alluvial silt to the north of Baroda.

But if the typical *broach deshi* cotton area in Southern Gujarat has a characteristic soil, it may be at once said that the climate is likewise quite characteristic, the total rain being greater than in most of the Indian cotton areas, though that rain is entirely concentrated in the months from June to October. From the end of this last month (October) to the following June, no rain usually falls. The average figures for Surat and for Jalalpur (in the Navsari cotton tract) for 44 years are as follows :—

Month	Surat	Jalalpur (Navsari)
	Inches	Inches
January	....	....
February	....	....
March	....	....
April	....	....
May	....	....
June	8·48	9·33
July	16·69	21·27
August	7·76	9·45
September	6·14	8·07
October	1·65	1·86
November	....	....
December	....	....
	40·72	49·98

Thus the average total rainfall in the tract is between 40 and 50 inches, but it is very variable, far more so than is usual in the American cotton

areas, producing cotton of similar staple. In Texas, for example,[1] the average rainfall in the growing months is as follows :—

Month	Rainfall in inches
April	3·0
May	3·7
June	3·1
July	3·0
August	2·1
September	2·9

The co-efficient of variability for the Texas rainfall is in April 52·0, in May 37·0, in June 50·0, and in July 46·8, or an average for these four most important months of 46·4. At Surat, on the other hand, the co-efficient of variability of the rainfall works out at 76·7 in June, 50·9 in July, 68·9 in August and 91·3 in September. This gives an average of 71·9, and shows how much more variable is the total rainfall in the Surat-Navsari area than it is in Texas.

This variability is illustrated by the following table showing the frequency with which certain ranges of total annual rainfall have occurred in the last 45 (Surat) or 44 (Jalalpur-Navsari) years respectively.

Range of total rainfall	Number of occurrences	
	Surat	Jalalpur-Navsari
Under 16 inches	2	1
16 to 24 ,, ...	5	2
24 to 32 ,, ...	5	4
32 to 40 ,, ...	11	7
40 to 48 ,, ...	8	7
48 to 56 ,, ...	7	5
56 to 64 ,, ...	5	7
64 to 72 ,, ...	1	6
72 to 80 ,, ...	0	3
Over 80 ,, ...	1	2
Total ..	45	44

At Surat the most frequent rainfall is between 32 and 40 inches, with a greater likelihood of it being over 40 inches than under 32 ; at Jalalpur-Navsari there is almost equal probability of the rainfall being anywhere between 32 and 64 inches.

[1] Kincer, J. B. Correlation of weather conditions and production of cotton in Texas, *Monthly Weather Review*, Vol. **43**, p. 64 (February 1915).

Treating the rainfall for each of the rainy months (June to September), the frequency of various amounts of rain is shown in the following table :—

Range of monthly rainfall	Number of Occurrences							
	Surat				Jalalpur-Navsari			
	June	July	August	September	June	July	August	September
Under 4 inches ..	15	3	13	22	11	1	8	13
4 to 8 " ..	10	3	16	11	11	5	13	17
8 to 12 " ..	8	6	7	5	10	4	11	3
12 to 16 " ..	6	12	3	5	3	5	4	6
16 to 20 " ..	2	8	5	1	6	8	4	5
20 to 24 " ..	4	4	1	0	1	5	4	0
Over 24 " ..	0	9	0	1	2	16	0	0

The most frequent rainfall in Surat is, therefore, below 2 inches in June, between 12 and 16 inches in July, between 4 and 8 inches in August and below 2 inches in September.

At Jalalpur-Navsari, on the other hand, a rainfall of anything below 12 inches in June is almost equally probable, while the most frequent amount of rain in July is over 24 inches. In August and also in September the commonest rainfall lies between 4 and 8 inches.

With the present information in hand it is difficult to establish a close correlation between the total rainfall and the average yield of the cotton crop in this region. The table at the end of the present chapter indicates the total rainfall and the average yield of seed cotton in cotton-*jowar* (*sorghum*) rotation on the Surat farm in every year since 1897. From this it will be seen that the 2 years of the highest yield, when crops of 643 lb. (1912) and 631 lb. (1920) of seed cotton were obtained, had a rainfall of 51·68 inches and 25·02 inches respectively. Similarly the lowest yield is given in 1900 (87 lb. of seed cotton) and 1911 (91 lb. of seed cotton) with a rainfall of 34·19 inches and 17·30 inches respectively. On the other hand, more than an average crop was obtained with a rainfall of 17·65 inches in 1918-19. It is, in fact, obvious that any connection between the total rainfall and the yield is very indirect, and that a much closer analysis is required if any correlation between rainfall and yield is to be established similar to that which has been made out to exist in Texas.

Temperature in the Surat cotton area.

The following table shows for each month at Surat (1) the average maximum shade temperature, (2) the average minimum shade temperature, and (3) the absolute maximum temperature.

Month	Average maximum shade temperature of 38 years	Average minimum shade temperature of 38 years	Absolute maximum shade temperature (average of 15 years)
	°F	°F	°F
January	86·6	57·7	96·3
February	88·3	59·4	100·4
March	95·7	66·5	108·1
April	99·3	73·4	110·4
May	96·9	78·7	109·9
June	93·0	79·5	102·5
July	87·4	78·1	96·3
August	86·7	76·9	92·4
September ..	88·7	75·7	98·4
October ..	94·0	71·9	103·6
November.. ..	91·8	64·5	100·6
December ..	87·8	59·0	96·2

The cotton is sown normally in June and the crop is reaped from February to April. The period of most rapid development of the plants is in October, after the rains are practically over, and when all chance of water-logging of the soil has ceased. October is, however, a very hot month, for though the minimum temperature is falling at that time of the year, the maximum reaches the highest point in the year, except for the hot weather from March to May. After October the rate of growth diminishes. The high temperature in March and onward causes very rapid and often premature opening of the later formed bolls. No frost is to be feared in this tract, the lowest temperature on our records being 42°F. in February 1911 and 47°F. in January 1906. Neither of these temperatures affected the cotton in any way.

The mean temperature during the growing period is considerably higher than that in other countries producing cotton of equal or better staple than that obtained from South Gujarat. The following figures may be interesting in this connection.

	Mean temperature	
	April to August	September to November
	°F	°F
America		
Mississippi	76	66
Texas	76	71
Georgia	69	62
Egypt		
Cairo	76	71
Surat	85	81

Humidity.

Seeing that the Navsari area produces the best quality of *broach deshi* cotton and this is probably the best staple cotton in India, the effect of the humidity of the atmosphere on the quality of this cotton cannot be left out of consideration. The Navsari tract is, in fact, the most humid in the India cotton areas, and the local belief is that this humidity has a good deal to do with the quality of the cotton produced. This is in accord with experience elsewhere. Orton[1] claims that humidity is a prominent factor in the production of nice staple and illustrates the fact by the case of Sea Island cotton.

Unfortunately there are no records of humidity for Navsari, where, as has already been stated, the best staple cotton in the tract is grown, but we have figures for Surat and can compare these with the data for other cotton growing countries. Dividing the growing period into two periods we have as follows :—

	Humidity	
	April to August	September to November
	Per cent.	Per cent.
America		
Mississippi	83	82
Texas	82	80
Georgia	79	84
Egypt		
Cairo	52	64
Surat	77*	57†

Orton, *U. S. Farmer's Bulletin* No. 302, p. 9 1907).

* June to September. † October to December.

The periods taken in the case of Surat and of the other tracts are slightly different, because the periods of growth are not quite the same. But they represent in each case, in the first column, the growing period of the plant, and in the second column, the flowering and boll forming period. They show a remarkable agreement between the humidity of the growing period at Surat and in the American cotton states, the figures being much higher than in Egypt. The flowering and boll forming period at Surat is, however, very much drier than in America and distinctly more so even than in Egypt. There is, in fact, a sudden decrease in humidity after September, as the following figures show :—

Month	Humidity at Surat
	Per cent.
June	73
July	78
August	79
September	78
October	57
November	57
December	59

Closely connected with the effect of temperature and humidity is the reported influence, in the region we are considering, of a cold north wind, locally called *himalu*, which tends to prevail at intervals from the latter part of December to the early part of February. During its prevalence the rapidity of development of the flowers is much reduced, and if the period coincides with the last stage of flowering, this suddenly ceases. The vigour of the plant also seems to be affected, as flowers producing bolls after such a period give seeds with a smaller weight than during the rest of the season.

Method of growing *Broach deshi* cotton.

With the soil and climatic conditions which has been described, the *broach deshi* cotton is grown in the following manner. The normal rotation is that of cotton and *jowar* (*Andropogon Sorghum*), and preparatory tillage for the cotton crop begins about the end of April by the harrowing of the fields to remove the stubbles of the previous crop. If manure is used in the rotation, it is usually applied in May or June, previous to the cotton crop, but this consists exclusively of cattle manure, and artificial manures have never been used, hitherto, on any large scale.

The seed is usually sown by a two-foot drill in June, at the first opportunity after the first rains. The seed rate is ten to twelve pounds per acre. In many

cases the first sowing fails, either owing to a break in the rains or, far more frequently, to excessive rain after sowing, and has to be repeated. After the plants have five or six leaves, they are thinned to a distance of one foot between the plants in the row. By this system the usual stand of plants obtained is about 75 per cent. The crop is intercultured with a blade harrow two or three times, and finally this process is repeated deeply in October either with the country plough or with the blade harrow.

The crop in a normal year flowers by December and the first crop of cotton is gathered at the beginning of March. It is harvested in three pickings. The normal crop of the Navsari-Surat area is 360 lb. of seed cotton per acre equal to about 110 to 120 lb. of clean cotton per acre.

The root system of cotton in South Gujarat is very deep, usually going to 3 to 3½ feet. The secondary root system is specially well developed, and commences from almost immediately below the surface level.

Table showing the rainfall and the yield of kapas per acre at Surat.

Year	Total rainfall in inches	Yield in lb.	REMARKS
1897	39·02	351	
1898	30·84	175	
1899	18·47	116	16 inches of rain in 11 days in July.
1900	34·19	87	Severe bollworm attack.
1901	16·80	129	Average yield of the whole experimental area.
1902	54·58	409	
1903	41·00	388	
1904	13·40	242	4·71 inches in July and 3·91 inches in September.
1905	19·82	370	8 inches of rainfall within 12 days.
1906	30·17	437	
1907	38·88	500	Sown in September. Early setting in of cold in November.
1908	47·45	426	
1909	53·31	397	
1910	32·09	415	
1911	17·30	91	North-eastern winds with cloudy weather in November.
1912	51·68	643	
1913	33·36	449	
1914	60·64	546	
1915	26·90	296	
1916	57·16	512	
1917	60·42	512	
1918	17·65	405	7·8 inches of fall one day.
1919	41·97	371	
1920	20·02	631	
1921	48·23	440	

II. THE HEREDITARY NATURE OF CERTAIN CHARACTERS IN *BROACH DESHI* COTTON.

In the author's previous Memoir he has discussed the question as to what characters are hereditary in *goghari* cotton. The general conclusions reached there for *goghari* cotton remain true for *broach deshi* cotton, but it is possible to consider the heredity of certain other characters, as the result of experiments more recently conducted.

(*a*) Hereditary nature of length of internodes on the main stem and monopodia.

The shape and character of a plant very largely depends on the length of the internodes on the stem. Long internodes mean a tall and sparse plant, short internodes mean a short and bushy plant. In cotton this difference is of very great importance, so that the question as to how far a type of cotton selected for its tall sparse habit will remain so in successive generations is of more than academic interest. The importance is particularly great in the Surat black soil during the first part of the growth, when the mortality is apt to be very great in low growing types. In 1921-22, for example, the mortality during the continuous rain from July to September was greater with plants of these types. Kottur[1] considers that, in Dharwar, short internodes often injuriously affect the development of fruiting branches. On the other hand, Burt[2] has found in Northern India that plants with long internodes are usually straggling in general habit, and tend to produce long weak lateral branches.

The hereditary character of this feature has been considered by Bennet[3] who states that the length of the internode is chiefly controlled by the breeding of the type, and that while the water supply affects the length, it acts similarly on long and short jointed types of cotton. Cook[4] also calls attention to the definitely hereditary character of the feature under discussion.

The results which the author has obtained in the last three years have confirmed for *broach deshi* cotton in every respect the views expressed by Bennet. While the relative length of the internode in different pure types remains similar, the actual length varies enormously in different years. Thus

[1] *Bombay Dept. of Agri. Bull.* 106 (1920), p. 17.

[2] *Pusa Agri. Res. Inst. Bull.* 88 (1919).

[3] Bennet. Method of breeding early cotton to escape boll weevil damage. *U. S. Farmers Bull.* 314 (1908).

[4] Cook. *U. S. Dept. Agri. Bur. of Pl. Indus. Bull.* 159 (1909).

to take two pure lines of *broach deshi* cotton, the actual average length of the internodes on the main stem from the first to the sixteenth internode was as follows :—

Strain	Length of internode at Surat		
	1919–20 cm.	1920–21 cm.	1921–22 cm
1–A Long Boll	21·8	30·6	14·5
1–A Cylindrical Boll	24·7	37·0	17·7

In 1919-20 the rainfall was heavy, with breaks; in 1920-21 the rain was in comparatively light showers, with breaks; in 1921-22 the rains were continuous and heavy from July to September. It will be seen that the relative difference is maintained, while the continuous rain of 1921-22 has reduced the length of the internodes enormously.

In this connection it is interesting to consider, in single strains, the relationship between the length of the several internodes on the monopodial branches, and the occurrence and length of the fruiting branches which arise from them. On these monopodia the fruiting branches arise (in the strains studied) chiefly from the fifth node and those beyond it. Wherever there is a short internode, however, the number of failures to form a branch at the succeeding node is very great, and this applies in the case of several strains. To ascertain how far the connection was a real one, the internodes on the monopodial branches of three strains, two of *broach deshi* and one of *goghari* were measured, and the success of branch formation at the succeeding nodes determined. One hundred or more plants were measured in each case, and the average taken.

Position of internode	Length of internode	*Goghari* "B-3" Percentage of failure of branches	Length of internode	1-A Long Boll. Percentage of failure of branches	Length of internode	1-A Cylindrical Boll. Percentage of failure of branches
	cm.		cm.		cm.	
4th to 5th ..	2·7	7·7	2·5	1·0	2·6	6·0
5th to 6th ..	2·2	91·4	1·9	96·9	1·9	93·0
6th to 7th ..	2·8	74·7	2·3	71·8	2·3	70·8
7th to 8th ..	3·4	8·6	3·0	2·2	2·9	6·3
8th to 9th ..	2·5	91·9	1·9	98·4	1·9	91·2
9th to 10th ..	3·8	10·4	3·3	2·2	3·2	5·5
10th to 11th ..	3·4	12·9	2·7	11·1	2·6	15·9
11th to 12th ..	3·2	73·9	2·2	88·1	2·4	77·7
12th to 13th ..	4·1	3·5	3·4	1·7	3·3	4·9
13th to 14th ..	3·3	39·8	2·1	61·9	2·2	47·2

Still another interesting connection appears to exist, at least in certain strains, between the length of the monopodial internodes, and the length (in nodes) of the fruiting branches (sympodia) which arise from them. Strains which have long monopodial internodes give short (few noded) fruiting branches and *vice versa*.

	Goghari B-3	1–A Long Boll	1–A Cylindrical Boll
	cm.	cm.	cm.
Average length of monopodial internode	3·1	2·5	2·5
Average number of nodes on fruiting branches from the monopodia ..	1·6	1·7	2·4

This point, however, needs considerably extended observations before the general applicability of the principle can be maintained.

(*b*) Hereditary nature of the length of petioles of leaves on the main stem.

The length of the leaf petioles is, of course, an exceedingly variable factor, depending on the vigour of the plants, the season in which they are grown, and the position of the leaf of the plant. Its close correlation with the size of the leaf blade, moreover, will be discussed later. But the relationship between the length of the petiole of leaves in a similar position on plants grown, side by side, seems constant, and hence the presumption is that we are in face of a hereditary character. The average length of the petioles of various leaves on the main stem in successive seasons (taken in each case from not less than 150 plants) is as follows, with two pure types of *broach deshi* cotton. The leaves are numbered from the base of the plants.

Leaf number	Length of the petiole					
	1–A Long Boll			1–A Cylindrical Boll		
	1919–20	1920–21	1921–22	1919–20	1920–21	1921–22
	cm.	cm.	cm.	cm.	cm.	cm.
1	..	2·18	1·3	..	2·30	1·5
2	..	2·25	1·4	..	2·72	1·6
3	..	2·52	1·7	..	3·41	1·9
4	..	2·72	1·8	..	3·47	2·0
5	..	2·79	2·1	..	3·70	2·3
6	..	2·85	2·4	2·96	4·04	2·6
7	2·74	2·86	2·6	3·09	4·13	2·7
8	2·86	3·13	2·7	3·30	4·27	2·8
9	3·03	4·00	2·7	3·68	5·30	2·9
10	2·96	4·40	3·1	3·93	5·70	3·5
11	3·12	4·76	3·2	4·27	6·00	3·7
12	3·20	5·08	3·3	4·35	6·30	4·0
13	2·96	5·30	3·5	4·35	6·30	4·2
14	2·76	5·44	3·8	4·30	6·80	4·3
15	..	5·61	3·8	..	6·90	4·4

(c) Hereditary nature of the number of monopodia in a strain of cotton.

The number of monopodia in a plant determines in a very large measure its growing character, and hence the question as to whether the tendency to produce monopodia is hereditary is a matter which has been always considered of great importance. Leake[1] considers that it is one of the fundamental differences between various types of cotton and bases his classification of cottons to a considerable extent on the frequency of the occurrence of and the number of monopodia. Kottur[2] likewise insists on the stability of this character in the types of *kumpta* (*Gossypium herbaceum*) cotton which he studied, and Burt[3] gives similar results for some of the Cawnpore-American types studied by him. The experience of most of the American workers is similar, though they insist[4] on the very considerable variation induced in any one type by changes in environment.

Using the same criterion of the hereditary character of any feature of a strain which the author has previously employed, namely, the constant relationship of the character in two or more strains in successive years, the number of the monopodia has been determined in a series of at least one hundred plants of five different strains in 1919-20, 1920-21 and 1921-22. The results which follow show the modal value for the number of monopodia in each strain in each year.

Strain	Number of monopodia (Modal value)		
	1919–20	1920–21	1921–22
B–1	6	6	6
C–1	5	5 to 6	5
1–A Long Boll	5 to 6	7	7 to 8
1–A Cylindrical Boll	6	7 to 8	8 to 9
1027–A. L. F.	6	7	7 to 8

[1] *Agri. Jour. India*, X, p. 116, Pl. 2 (1915).
[2] *Poona Agri. Coll. Mag.*, X, No. 1.
[3] *Pusa Bull.* No. 88 (1919).
[4] Hudson. *Arkansas State Expt. St. Bull.* No. 168 (1920).
U. S. Bureau of Plant Industry Bull. No. 159 of 1909. Local adjustment of cotton varieties.

The results indicated in these figures are more strongly illustrated by a comparison of the frequency curves of the number of monopodia in the series studied, and the following two figures compared these for two of the years studied in two of the above types. The general result is to confirm, for the *broach deshi* cotton studied, the observations recorded by other workers for other cottons, that the tendency to form few or many monopodia is inherited.

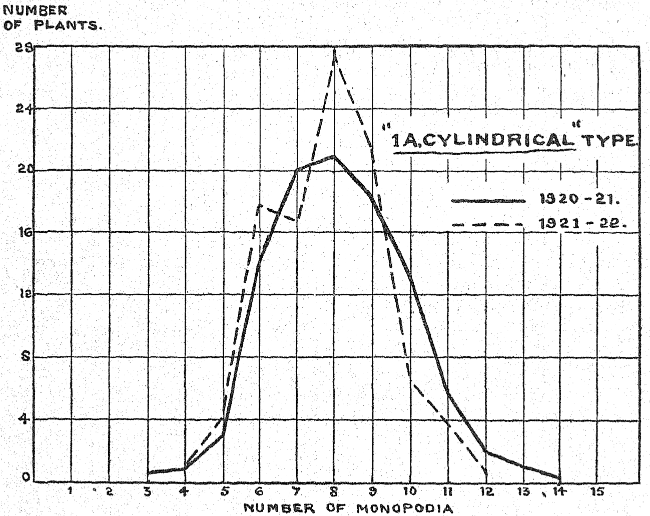


FIG. 1. Variation in the number of monopodia in 1920–21 and 1921–22.

(*d*) Hereditary nature of the position of the first fruiting branch (sympodium) formed on the main stem.

Since a considerable proportion of the yield of cotton given by a plant is produced on fruiting branches (sympodia) borne on the main stem, and as this is the earliest cotton borne on the plant, it is obviously of considerable interest to know whether the faculty to form such branches at a particular position

in the plant is hereditary, and can be relied upon to recur from generation to generation. The actual position of the first fruiting branch, however, varies very widely in different cottons. In Sea Island cotton (*Gossypium*

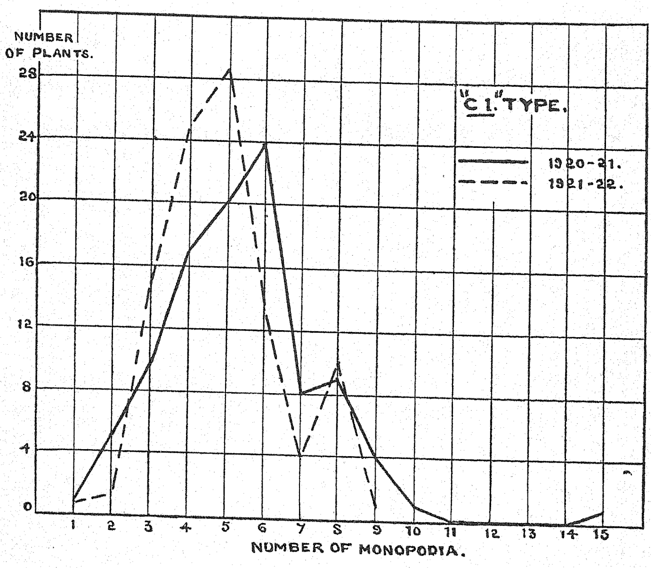


FIG. 2. Variation in the number of monopodia in 1920–21 and 1921–22.

barbadense) the first fruiting branch arises from the eighth to the fourteenth node[1], in American cotton (*Gossypium hirsutum*) it usually appears at the fifth or sixth node, in *kumpta* cotton[2] at Dharwar the point of origin is the seventh or eighth node.

In the author's experiments, three strains of *broach deshi* cotton have been studied for three years, and the position of the node from which the first

[1] *Agri. News, Barbados*, XIX, p. 101.
[2] *Mem. Dept. Agri. India, Bot. Ser.*, X, No. 6, p. 251 (1920).

fruiting branch arises determined for a series of plants all growing three feet apart. The modal value for the results is as follows :—

Strain	Position of first fruiting branch (Modal value) 1919-20	1920-21	1921-22
C-1	17	13	17 to 18
1-A Cylindrical Boll	19	15	20
1-A Long Boll	18 to 19	14	19 to 20

The variation, however, in one and the same season in a pure strain is fairly wide, and different plants growing under identical conditions vary by six to eight nodes. The co-efficient of variability in a single season with regard to the above three strains is :—

Strain.		
C-1	1920-21 ..	12·8
	1921-22 ..	7·0
1-A Cylindrical Boll	1920-21 ..	11·0
	1921-22 ..	6·0
1-A Long Boll	1920-21 ..	11·5
	1921-22 ..	6·6

The character is, therefore, very variable. The relative difference in the modal value is maintained, however, indicating the character to be of hereditary nature.

(*e*) HEREDITARY NATURE OF THE SHEDDING OF FLOWER BUDS.

The yield of cotton from any plant is determined by the number of sound bolls produced, but this number is often far less than the possible production. There is, in fact, in every type of cotton and under every condition of cultivation a loss of potential yield due to shedding of flower buds, flowers, or bolls during every stage of their growth. At present we will limit our consideration to the loss of flower buds. This loss varies in different cottons from almost *nil* in Egyptian cotton to nearly seventy per cent. in the *broach deshi* cotton which we are now considering.

In the *broach deshi* cotton in 1919-20, the loss at Surat was found to be 71·7 per cent., in the following year it was 60·8 per cent., and in 1921-22 it was 58·2 per cent. In American cotton it seems to vary between 14 and 17 per cent.[1] and in Sea Island cotton it may rise to from 40 to 50 per cent.[2]

[1] Lloyd. *Annals of New York Academy of Sciences*, Vol. 29, pp. 82 and 84.
[2] *West Ind. Bull.*, XVIII, p. 191.

Naturally this loss is due to many causes. Attack by insects accounts for a certain proportion; unsuitable cultivation may lead to much loss; reduction in the moisture content in the soil also accounts for a certain amount of shedding. But in spite of the influence of all these and several other environmental conditions, the various types of cotton *do* seem to have varying capacity to mature the flower buds which they form.

In this connection a very interesting observation has been made by Harland[1] in the West Indies (St. Vincent). He found that, in certain types of native cotton, the tendency to shed flower buds was highly developed, and that when these were crossed with Sea Island cotton the feature appeared to be inherited as a dominant character. Again Cook[2] maintains that the faculty of shedding flower buds is a hereditary characteristic of certain brachytic types of cotton which he has described.

The general position with regard to the loss of flower buds in Lower Gujarat has been already noted and the seriousness of the loss on this account described. It may be worthwhile, however, giving the results of observations on the matter in more detail. In the first place, the number of flower buds, which are shed, varies very much in different parts of the season. The method of estimation was as follows. The number of flower buds formed up to a certain date (say 5th November) was counted. Other observations had shown that it required not more than a month for a flower bud to develop into a flower, and so all flowers formed up to one month later (say 5th December) were counted and the number compared with the number of flower buds. The results by this method in 1920-21 and 1921-22 are shown in the following table for a number of pure strains :--

Strain	Percentage of flower buds forming flowers			
	1920–21		1921–22	
	Buds formed to November 5th	Buds formed in whole season	Buds formed to December 9th	Buds formed in whole season
B-1	26·0	34·2	22·1	37·6
C-1	17·0	39·0	26·1	40·3
1-A Long Boll	7·8	39·3	19·5	39·7
1-A Cylindrical Boll	14·2	43·2	33·3	46·1
Selection 2	17·5	43·2	32·0	43·1
1027-A. L. F.	11·3	36·5	28·2	44·1

[1] *West Ind. Bull.*, XVI, p. 74.

[2] Quoted by Lloyd, *Jour. Agri. Res.*, III (*February* 1915).

In the early part of the season, therefore, the loss of flower buds by shedding is apparently greater than in the latter part of the flowering period, and seems to vary very considerably in different strains grown under identical conditions. This difference between the success of the flower buds at different parts of the season seems, in Southern Gujarat, to depend mainly upon the period and virulence of bollworm (*Earias* spp.) attack and in the number of buds present when the bollworm attack is at its highest. There seems also to be a definite difference between the susceptibility of the strains to bollworm attack, as is illustrated by the behaviour of strain "B-1" in the above table, where it shows a very high proportion of success in the early part of the flowering (period of bollworm attack), but the lowest percentage of success taking the whole season together.

The case of this strain "B-1" is of special interest, for here the final low percentage of success appears to be due to the hereditary tendency to produce a larger number of flower buds in proportion to the vegetative growth than in any other case. This clustering together of the flower buds seems closely to be connected with the loss of buds, more particularly towards the end of the season when the water supply is short. The clustering together of flower buds can be said to exist when the number of flower buds on each fruiting branch is more or when the number of fruiting branches is more in relation to the growth in nodes of vegetative branches, *i.e.*, monopodia and axillary vegetative branches. These two can best be expressed together by comparing the ratio of the number of flower buds to the growth in number of nodes of vegetative branches (*i.e.*, monopodia and axillary vegetative branches). The difference between this and other strains is shown in the following table, indicating the ratio of the number of flower buds to nodes on the vegetative branches of the plant.

Strain	Ratio of flower buds to nodes of growth	
	1920–21	1921–22
B-1	1·03	1·25
C-1	0·54	1·17
1-A Cylindrical Boll	0·50	0·90
Selection 2	0·55	1·00
1027-A. L. F.	0·60	0·88

Similarly the structure of the plant in certain cases as in "Selection 2" (where the bracts have a very spreading character in the early stages), or in "C-1" (where there is a more open habit of growth than in other strains) leads to a greater power of resisting the bollworm attack, and hence these strains give a large proportion of success in the earlier part of the flowering period. But making every allowance for all these environmental or structural differences, the relative position of the strains in the different years, so far as shedding of flower buds is concerned, remains sufficiently similar for us to say that there is certainly a hereditary factor involved in this case.

(*f*) Hereditary nature of the shedding of flowers and young bolls.

But the shedding of potential cotton-producing organs is not limited to the flower buds. In the *broach deshi* cotton this is by far of the greatest importance, but there is also, here as elsewhere, a considerable amount of loss of flowers and young bolls.

The extent to which this loss of flowers and young bolls takes place varies very much. Lloyd (*l. c.*), to whom we owe one of the most illuminating studies of this question, found that in his work the percentage of loss in 1911 was 42·1, while in 1912 with American Upland cotton it was 28·0. A similar result was obtained with Sea Island cotton in the West Indies, where in 1916-17 only 17·2 per cent. of flowers produced bolls, 48 per cent. in 1917-18, and 37 per cent. in 1918-19.[1] In Egypt Balls[2] gives 60 per cent. as being the normal proportion of flowers which produce bolls.

The causes which lead to this enormous loss have been investigated by many workers, and it has been ascribed to root pruning by deep cultivation, to excessive vegetative growth during the flowering period, to heavy rain, to severe drought, to overcrowding of the plants, to insufficient pollination from whatever cause, to insect attack whether by aphis, bollworm or boll-weevil, and to a number of other causes. But as noted by the workers in Egypt, there is a variable amount of shedding under perfectly normal conditions, dependent on the actual strain in cultivation, which they term "constitutional shedding." This has also been noted elsewhere, and has been attributed by Foaden[3] to the development of a large number of flowers

[1] Harland. *West Ind. Bull.*, XVIII, p. 24.

[2] Balls. *The development and properties of raw cotton.*

[3] Foaden. *U. S. Bureau of Plant Industry Bull.* No. 62.

to leaf surface and by Kottur[1] to the bushy or erect character of the plants.

In the author's own experiments the various pure strains which he has isolated from *broach deshi* cotton have shown considerably different capacities to bring the flowers to maturity when grown under identical conditions. The actual results, in percentage of bolls to flowers which opened, in three years are as follows :—

Strain	Percentage of ripe bolls to open flowers		
	1919–20	1920–21	1921–22
B–1	40	31·5	29·5
C–1	51	48·5	34
1–A Long Boll	..	38	32
1–A Cylindrical Boll	53·	40	32
Selection 2	47	33·5	34
1027–A. L. F.	49	36	38·5

The differences between the different seasons were great, and generally the percentage of ripe bolls to open flowers is much less than in Egypt. But the loss is also seen to be in a measure a matter of strain, and those strains which give a higher or a lower percentage of success in one season will also tend to give generally a higher or lower percentage in another year with very different climatic conditions. This does not always appear, but there is sufficient constancy in the relative position of the various types to justify the conclusion that the tendency to a great or less proportion of shedding of flowers and young bolls is a hereditary character, though it is very largely masked by the effect of different environmental factors.

While the question of flower and boll shedding is under consideration it may be noted that the flowers formed at different stages of the season have by no means the same chance of producing successful bolls. Observations on this point were made in both 1920-21 and 1921-22, and the

[1] *Bombay Dept. of Agri. Bull.* No. 106 (1920), p. 18.

following table shows the results with three pure strains in these two years :—

Period of flowering	Flowers formed producing ripe bolls					
	B-1		1-A Long Boll		1027-A. L. F.	
	1920-21	1921-22	1920-21	1921-22	1920-21	1921-22
	%	%	%	%	%	%
First three weeks ..	40	21·5	..	15	..	57
Fourth week ..	79	38·5	63·5	16·5	72·5	50
Fifth „ ..	65	55	75	32	79	45
Sixth „ ..	49·5	61·5	72	56·5	69	65·5
Seventh „ ..	14	58	67	64·5	36	70
Eighth „ ..	3·5	58	38·5	63	18·5	58·5
Ninth „ ..	3·0	54	16	58	8·5	45
Tenth „ ..	..	20	5	28·5	0·5	14
Eleventh „ ..	..	2·5	..	4	..	1·5

The early flowers in most strains and the late flowers in all strains are very largely lost. The early loss seems chiefly due to the attack of bollworm and wherever bolls are produced from the flowers opening at this period the produce is always much attacked by this insect.

This is shown by the number of seeds per boll obtained at different parts of the season, a small number indicating that the remainder have been destroyed by insect attack. The following table gives observations on this point.

Strain	Seeds per boll—(average)			
	To December 12th	December 13th to January 13th	Whole Season	Healthy bolls
1 A Long Boll	13·4	18·6	19·2	22·2
1027-A. L. F.	8·4	15·5	16·4	21·0

The loss at the end of the flowering season may be due to water shortage, though on this point we have no evidence. But it is certain that at the time

when the percentage of successful bolls begins to go down, the seed weight also declines, leading consequently to a reduction of lint weight per seed and per boll.

One more point of interest arises in connection with the shedding of flowers and young bolls. Is the proportion of shedding affected by the class of branch on which the flowers are borne? The following table shows the records made on this point in 1919-20, though it must be recognized that the effect of the character of the branch on which bolls are borne may easily have been masked by other factors. So far as the figures show anything, they indicate little influence of the branch bearing the flowers on their success.

Strain	Percentage of successful flowers		
	On primary fruiting branches	From monopodia	From axillary vegetative branches
Selection 2	44	50	47
1-A Cylindrical Boll	57	51	55
1027-A. L. F.	65	43	48
C-1	50	50	51
B-1	24	39	43

The general observations made in connection with the shedding of flower buds, of flowers and of bolls lead to a much higher conception of the loss on this account in South Gujarat than is usually held. The total percentage of loss, in all these forms with several pure strains, has been as follows :—

Strain	Total loss by shedding (Percentage of bolls to flower buds)	
	1920–21	1921–22
B-1	10·7	11·0
1-A Long Boll	14·8	12·7
1027-A. L. F.	13·5	16·8

It is difficult to conceive that the percentage loss by shedding represents always over 83 per cent. of the flower buds formed, and with some strains may go up to 89 per cent. The importance of checking, at any rate, some portion of this loss, whether by the selection of less shedding strains or by measures to deal with the factors of environment which lead to it, obviously cannot be over-estimated.

(*g*) Hereditary nature of early or late flowering.

The appearance of flowers and the rapidity of flowering depends on the successful growth of the flower buds formed. The course of normal flowering is usually something as follows. The seed is sown in June, the first flower buds appear from five to ten weeks later, and the first actual flowers open from the fifteenth week onward. The actual flowering lasts from eight to twelve weeks, approximately from November to the latter part of January, and bolls ripen from the beginning of March to the middle of April.

The proportion of the total flowers produced and borne in the last part of the flowering season is a measure of the lateness of the strain grown, and the following figures show for four of our *broach deshi* strains what has been found. The period of flowering in different years is not the same owing to the variable weather conditions, but in 1919-20 and 1921-22, the last two weeks during which flowers were formed in any of the strains studied were the twenty-eighth and twenty-ninth weeks from germination. In 1920-21, the period of growth was shorter and the flowering ceased after the twenty-second or twenty-third week from the time of germination.

Strain	Proportion of total flowers produced in the last two weeks		
	1919–20	1920–21	1921–22
C-1	14·7	35·1	9·0
1-A Long Boll	20·2	44·0	15·4
1-A Cylindrical Boll	10·1	43·3	12·4
Selection 2	14·7	30·8	3·1

The strain "1-A Long Boll" retains its position as the latest type of these cottons throughout these seasons though they are different fundamentally in character, and the relative position of the others is very largely maintained. The evidence of these figures is, therefore, that the character of earliness or lateness of flowering is hereditary, though the actual dates of flowering are much modified by the environment in any specific season.

(*h*) Hereditary nature of the size and shape of the bolls.

In the author's previous Memoir, it was shown that the size of the boll was hereditary in *goghari* cotton, taking the quantity of *kapas* per boll as a measure of the size. This is not a perfect measure of the size owing to the occurrence of three and four celled bolls. The latter are larger in size, but the extra number of seeds and hence the extra amount of *kapas* they contain is by no means proportionate to the increase in size. In one of the *broach deshi* strains ("B-1") a large number of three-celled and four-celled bolls were examined in 1920-21 and in two others ("1-A Long Boll" and "1027-A.L.F.") in 1921-22, and the extra number of seeds in the four-celled bolls determined. The results were as follows:—

Strain	Number of seeds	
	3-celled boll	4-celled boll
B-1 (1920-21)	19·6	24·7
1-A Long Boll (1921-22)	22·3	26·5
1027 A. L. F. (1921-22)	22·3	28·3

Thus the addition of approximately 33 per cent. to the size of the boll has led to an increase in number of seeds of 26 per cent. with "B-1," of 19 per cent. with "1-A Long Boll" and of 27 per cent. with "1027-A.L.F." A similar variation due to the presence of four-celled bolls has been noticed by Wells[1] in 1919 and Gilpin in 1920. As this variable factor occurs, it is necessary to investigate the extent to which the frequency of four-celled bolls is hereditary before the size of the bolls can be used as a measure of the relative amount of *kapas* they are capable of giving. The matter has been studied in five strains of *broach deshi* cotton in 1920-21 and 1921-22 with the following results:—

Strain	Percentage of 4-celled bolls	
	1920–21	1921–22
1027-A. L. F.	23·0	13·8
1-A Long Boll	17·0	5·8
C-I	11·0	2·9
Selection 2	5·0	1·2
1-A Cylindrical Boll	1·0	0·3

[1] *Jour. Agri. Res.*, XXI, p. 238.

These figures show that the relative position of the strain in this particular is maintained, although the proportionate reduction is not equal with the different ones. The character is obviously hereditary, and the relative size of the bolls in different types of cotton may be used as a rough measure of the relative yield of *kapas*. Taking one hundred bolls in each case, the amount of *kapas* obtained in each of the last three years was as follows, with the five strains named below.

Strain	QUANTITY OF *kapas* PER 100 BOLLS		
	1919–20	1920–21	1921–22
	grm.	grm.	grm.
1027–A. L. F.	214·9	222·3	234·0
1–A Long Boll	226·6	239·8	251·5
C-1	165·2	169·6	191·8
Selection 2	198·9	204·7	231·6
1–A Cylindrical Boll	203·2	198·9	224·6

The relative difference is maintained year after year in all the strains except in "Selection 2" in 1919-20, in comparison with "1-A Cylindrical Boll." The difference in these in any year is, however, very small, probably less than the error of sampling.

One more point of interest arises in connection with the relative size of bolls as affected by the type of branches on which they are borne. Kottur has stated (*l. c.*) that in *kumpta* cotton nine bolls on primary fruiting branches (sympodia) are normally equal to ten on secondary fruiting branches borne on monopodia and to twelve on fruiting branches arising from axillary vegetative branches. This was studied in one of the *broach deshi* types ("1-A Long Boll") in 1919-20, with the following results, based on actual measurement of the bolls in each case. The length of the bolls was taken from the gland to the tip of one of the cells, and the width was the greatest width of the cell of a boll.

Kind of branches	Length of boll	Width of cell
	cm.	cm.
(1) Bolls on primary fruiting branches ..	3·6	2·2
(2) Bolls from monopodia	3·6	2·2
(3) Bolls from axillary vegetative branches ..	3·7	2·2

Hence, the difference noticed by Kottur does not seem to occur, and in this strain the bolls are of very nearly equal size on whatever part of the plant they are borne.

In 1919-20 only two measurements were made, namely, the length from the gland to tip and the greatest width of the bolls. The whole records for each of the pure types of *broach deshi* cotton as grown in Surat are shown in the accompanying table. This distinctly shows that the relative difference is maintained.

Strain	Measurement of bolls					
	Length from gland to tip			Greatest width of one cell		
	1919–20	1920–21	1921–22	1919–20	1920–21	1921–22
	cm.	cm.	cm.	cm.	cm.	cm.
1-A Long Boll ..	3·8	3·6	3·6	2·4	2·2	2·2
1027-A. L. F. ..	3·6	3·4	3·4	2·2	2·1	2·2
1-A Cylindrical Boll ..	3·2	3·2	3·1	2·2	2·1	2·1
Selection 2 ..	3·2	3·1	3·1	2·2	2·2	2·2
C-1	3·1	2·9	3·0	2·0	2·0	2·0
B-1	2·9	2·9	2·9	2·0	2·0	2·0

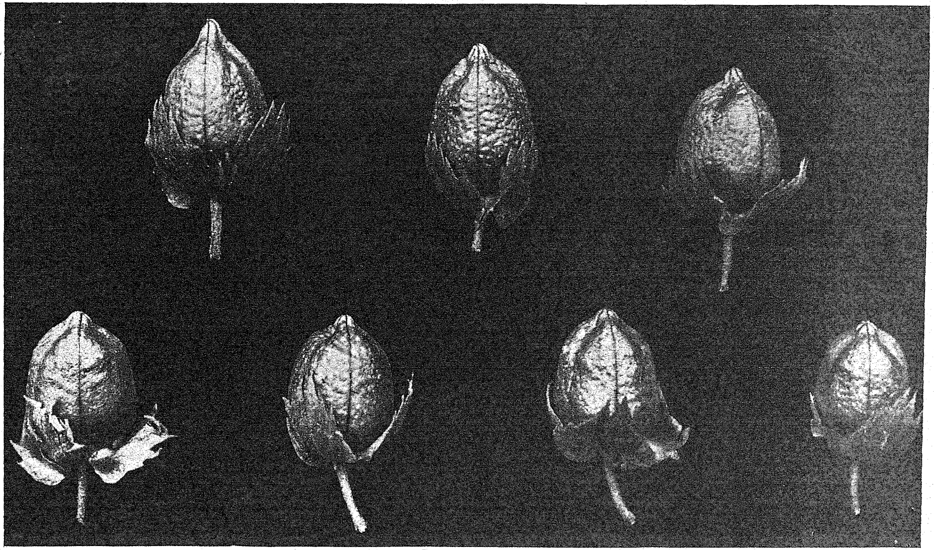
While we have the constancy of type in the bolls of the same pure strain, from year to year, the ordinary *broach deshi* cotton grown is very variable indeed. Plate I shows the type of boll represented by the different strains considered in the present paper. The experience gained with each of these pure strains for a series of years bears, however, no doubt as to the hereditary character of the shape and size of the boll in each of them.

(*i*) Hereditary nature of the length of the seed hairs (staple).

The variation in the length of the seed hairs, even in a uniform pure type, has been long known to be very great, but there seems in each case a limit to the variability. Balls[1] from his work in Egypt considers that every strain

[1] Balls. *Mendelian studies in Egyptian cotton.*

PLATE I.



TYPES OF BOLL IN BROACH DESHI COTTON.

Upper row (left to right)

(1) Boll of strain "I-A-Long Boll."
(2) and (3) Bolls of strain "1027, A.L.F."

Lower row (left to right)

(1) Boll of strain "Selection 2" spreading bracts.
(2) Boll of strain "1-A. Cylindrical Boll"
(3) Taper and small boll of strain "C-1."
(4) Small and almost cylindrical Boll of strain "B-I."

of cotton has the property of forming seed hairs of a minimum length, and that this will not vary more than 25 per cent. under extreme conditions. He[1] also has found that the first pickings in Egypt give long lint, while from the later pickings, various lengths may be found in different seeds from the same boll. He[2] also maintains that variation in the water content of the soil at certain stages after the opening of the flower, whether from variations in temperature or otherwise, affect the length of the seed hairs, as the growth of the hairs is at its maximum between the fifteenth and twenty-first day after the flower opening. Further, the length of the lint varies with the position of the seed in the boll, and the position of the lint hairs on different seeds.

These last points have also been noticed by other workers. Cook[3] states that in Upland American cotton long hairs occur at the end of the seed and short fibres at the base. In Egyptian cotton (*Metafifi*) the longest fibres are found in the middle of the seed and short fibres on the ends. Kottur (*l. c.*) in *kumpta* cotton has found that the tip of the seed bears short hairs and the base bears long ones. The seeds at the apex of the cells of the boll also produce shorter hairs than other seeds in the same boll.

The observations which have been made in connection with the present study of *broach deshi* cotton indicates that the seeds from the middle of the boll always have longer hairs, while those at the bottom, and specially on the side of the seed facing the base of the boll, have hairs of inferior length. The difference in the length of hairs from the different parts of the boll is shown by the following measurements.

Mean length of lint hairs from seed at middle of boll (mean of 280 observations)	2·4 cm.
Mean length of lint hairs from seed at the base of a lock ..	2·2 cm.

The relative length of the lint hairs from different parts of the same seed in the *broach deshi* cotton types is slightly different from that described by Kottur for the other variety of *Gossypium herbaceum* which he studied. The hairs at the tip are the shortest, while those in the middle are the longest.

As regards the variation in length in the different parts of the season, as represented by the first, second and third pickings, the following figures show

[1] Balls. *Notes on Mendelian heredity in cotton* at Cairo.

[2] Balls. *The development and properties of raw cotton,* p. 115.

[3] *U. S. Bur Plant Industry Bull.,* No. 156, p. 16.

the differences in the mean length in the different parts of the seed, for three pure strains.

Strain	Mean length of seed hairs		
	First picking	Second picking	Third picking
	cm.	cm.	cm.
	1. Tip of the seed.		
1027–A. L. F.	2·1	2·0	1·9
Selection 2	2·1	2·1	1·9
C-1	1·7	1·7	1·7
	2. Middle of the seed.		
1027–A. L. F.	2·6	2·5	2·3
Selection 2	2·4	2·5	2·3
C-1	2·1	2·0	2·0
	3. Base of the seed.		
1027–A. L. F.	2·4	2·3	2·2
Selection 2	2·3	2·4	2·2
C-1	2·0	2·0	1·9

From these figures, it is evident that the hairs from the first picking are usually the longest, though the produce of the second picking is very little less in length. The last picking is, however, uniformly inferior in staple.

The variation in the length of the staple in the produce of different kinds of branches was studied in two of the pure strains in 1919-20 with the following results: —

Strain	Mean length of seed hairs		
	On primary fruiting branches	On branches arising from limbs	On branches arising from axillaries
	cm.	cm.	cm.
	1. Tip of the seed.		
1–A Long Boll	2·2	2·1	2·2
1–A Cylindrical Boll	2·2	2·0	2·2
	2. Middle of the seed.		
1–A Long Boll	2·5	2·4	2·5
1–A Cylindrical Boll	2·5	2·4	2·5
	3. Base of the seed.		
1–A Long Boll	2·3	2·2	2·3
1–A Cylindrical Boll	2·4	2·3	2·4

The staple of the produce from the fruiting branches borne on the primary monopodia (limbs) is very slightly shorter than from the bolls borne on the other two types of branches. This clearly proves that the increase or decrease in the number of limbs in different strains of a variety will only very slightly affect this character.

The system of measurement of the staple of the lint hairs produced by a type of cotton is a matter of importance in any critical study of this question. Harland measures it on five seeds of each type. Balls recommends that seven seeds of each type should be used for the purpose and the average taken, while the West Indies authorities advise that ten seeds taken at random should be employed, the average of these being taken as before. The author has adopted the system of measuring the lint on the seeds in half of a cell, taken from three bolls to be chosen from all pickings of a single plant when the comparison is to be made of the produce of individual plants of a strain. When comparisons of strains are to be made, the hairs of one hundred seeds are measured, again all the seeds of half a cell being taken. The measurements are always taken at the tip, the middle and the base of each seed.

Using this method, it is possible to get very reliable results in testing whether the relative length of the lint hairs in different strains is maintained in different years and so a determination made as to whether this character is hereditary or not. The actual results with five pure strains are as follows :—

Strain	Average length of seed hairs								
	1919–20			1920–21			1921–22		
	Tip	Middle	Base	Tip	Middle	Base	Tip	Middle	Base
	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
1027–A. L. F.	2·2	2·7	2·4	2·0	2·5	2·3	2·4	2·9	2·8
1–A Long Boll	2·3	2·5	2·4	2·0	2·5	2·5	2·1	2·6	2·6
1–A Cylindrical Boll ..	2·2	2·5	2·4	1·7	2·2	2·1	2·1	2·6	2·6
Selection 2	Not ascertained			2·0	2·4	2·3	2·1	2·5	2·4
C-1	Do.			1·7	2·0	2·0	2·0	2·5	2·4

From these figures it will be seen that there are wide variations in staple of the cotton produced by a pure strain from season to season. In 1920-21, a dry season, the shortest staple was obtained, though the reduction was much greater in some types (as for example, " 1-A Cylindrical Boll ") than in others

(as for example, "1-A Long Boll"). The type producing the longest staple ("1027-A.L.F.") is, however, the longest throughout, and likewise that producing the shortest ("C-1") is the shortest throughout. Thus in spite of seasonal variation, the relative difference is maintained, and the character is definitely of hereditary nature.

(*j*) Hereditary nature of the seed weight.

Workers with other species and varieties of cotton have already determined that with their types the seed weight is a definitely hereditary character. Balls[1], for example, has found this with Egyptian cotton, and Harland has stated that there is a strong correlation between the parent and the mean of the progeny in respect of the characters of the lint length, lint weight, and seed weight. In the author's own previous work he has adduced evidence that the seed weight is hereditary in the *goghari* variety of *Gossypium herbaceum*, but the matter is worthy of further discussion on the basis of observations made on *broach deshi* cotton at Surat.

In a pure strain the weight of the seed may vary from a number of causes :—

(1) Partially malformed plants give light seed.

(2) Seeds from badly opened bolls are light, whatever may be the causes of the bad opening of the bolls. Such bad opening is most frequently due to insect attack.

(3) Seeds from four-celled bolls are usually lighter than those from three-celled bolls.

(4) The previous treatment of the land as regards manure or rotation seems to have some effect. Thus cotton following green manuring of the land with sann-hemp (*Crotalaria juncea*) combined with fallow, gives heavier seeded cotton than when, as is usual in Surat, the cotton crop follows *jowar* (*Andropogon Sorghum*). The following figures illustrate the last of these points :—

	Average weight of seeds	
	1916–17	1917–18
	mg.	mg.
Cotton after sann-hemp and fallow ..	55·1	59·1
Cotton after *jowar*	49·8	57·3

[1] Balls. *Cotton Plant in Egypt*, 1912, p. 167.

There is also some evidence that cotton following groundnut gives lighter seed than when it follows *jowar*, but the results are not yet certain.

(5) The different pickings of the cotton give *kapas* with varying seed-weight. In this matter the following represents the results of three seasons.

Strain	Average weight per seed in 1919–20		
	First picking	Second picking	Third picking
	mg.	mg.	mg.
B–1	55·7	51·0	....
C–1	52·2	50·6	49·3
1–A Long Boll	61·9	60·0	....
1–A Cylindrical Boll	60·0	55·4	....
Selection 2	61·2	59·7	56·5
1027–A. L. F.	66·0	62·2	60·6
	Average weight per seed in 1920–21		
B–1	54·1	50·4	43·1
C–1	56·2	55·1	45·8
1–A Long Boll	69·6	67·2	60·9
1–A Cylindrical Boll	59·0	57·3	56·5
Selection 2	64·5	64·6	63·8
1027–A. L. F.	62·2	61·2	59·6

From these figures, it is clear that there is a progressive decline in the seed weight through the season. This rule has practically no exception though the amount of such decline is very different in different types and in the different years. This point was made particularly clear in the results of 1921-22 where the seeds in the bolls produced from flowers in the last weeks of flowering (10th and 11th weeks) were compared with the average of the season. The fall from the average of the seeds in question was as follows :—

Strain	Decrease in seed weight from flowers in the	
	10th week	11th week
	mg.	mg.
B–1	5·7	No crop
C–1	5·5	Do.
1–A Long Boll	3·8	7·0
1–A Cylindrical Boll	5·9	No crop
Selection 2	4·8	Do.
1027–A. L. F.	7·8	Do.

Despite all these causes of variation, there is no doubt, as the following table indicates, that the heavy seeded strains (like "1027-A. L. F.") and the light seeded strains (like "B-1" and "C-1") maintain their respective characters, and that the character is definitely hereditary in these strains of *broach deshi* cotton.

Besides this, it will be seen that different seasons have a varying effect on the seed weight on different types. Each average weight given is from two thousand seeds.

Strain	Average weight per seed			
	1918–19	1919–20	1920–21	1921–22
	mg.	mg.	mg.	mg.
B–1	55·1	54·0	52·9 51·3	55·4 55·1 51·3
C–1	50·4	50·4	55·4 52·4 52·2	55·4 51·3 48·5
1–A Long Boll	61·2	59·4	61·5 64·2 60·6	65·1 64·6 63·2
1–A Cylindrical Boll	..	59·7 58·5	56·8 56·5 55·7	64·6 64·2 62·2
Selection 2	60·9	60·3	62·5	63·9 64·6
1027–A. L. F.	63·2	63·2	64·2 67·0	74·5 69·2 67·2

(*k*) Hereditary nature of the weight of lint per seed (lint index).

It will be shown later (Chapter III) that there is a reliable positive correlation between the mean weight of lint per seed and the mean weight of the seed itself in the strains of *broach deshi* cotton with which we are dealing, and that hence a larger seed has a greater potential lint bearing capacity. But for the moment, let us consider the actual weight of lint per seed in the lint

index as a factor independent of the weight of the seed itself. A detailed analysis of the character indicates that it depends on three factors :—(1) The number of lint hairs, (2) the length of the individual hairs, and (3) the thickness of the hairs. Of these, the first is the most important. If the number of lint hairs, that is to say, if the surface of the seed and the frequency of the hairs, is the same, the lint index depends on the length and thickness of the fibres. In selecting plants by lint index, therefore, care has to be taken that the raising of this index does not merely mean increasing the coarseness of the fibres.

The variation in the lint index in different parts of the season with pure strains of *broach deshi* cotton are shown by the following data for the different pickings in 1919-20 and 1920-21.

Strain	LINT INDEX.*			
	1st picking	2nd picking	3rd picking	4th picking
		1919–20		
	grm.	grm.	grm.	grm.
B–1	2·6	2·6	....	....
C–1	2·2	2·5	2 6	....
1–A Long Boll ..	3·6	4·1	....	....
1–A Cylindrical Boll ..	2·9	3·2	....	....
Selection 2	3·0	3·5	3·4	....
1027-A. L. F.	2·7	3·1	3·0	....
		1920–21		
B–1	2·9	2·8	2·2	....
C–1 ..	3·1	3·1	2·6	....
1–A Long Boll ..	4·3	4·2	4·0	3·4
1–A Cylindrical Boll ..	3·9	3·7	3·7	3·0
Selection 2	3·8	4·0	3·9	....
1027 A. L. F.	3·4	3·6	3·5	....

The variation not only in the index itself, but also in the relationship between the lint index at different parts of the season is very great. In 1919-20, the second picking gives in almost all cases a higher figure than the first and the third is nearly as high as the second. In 1920-21, on the other hand, the first and the second pickings differ little and the later ones are distinctly lower. A lower index at the end of the season seems a regular thing, for in 1921-22, the seeds in the bolls produced from flowers in the last week of flowering (10th and 11th weeks) gave consistently a considerable

* Weight of lint per 100 seeds (according to the usual standard).

decrease in the lint index on the average for the season. The actual figures were as follows :—

Strain	Decrease in lint index from flowers in the	
	10th week	11th week
	grm.	grm.
B-1	0·18	....
C-1	0·27	....
1-A Long Boll	0·21	0·56
1-A Cylindrical Boll	0·19	....
Selection 2	0·30	....
1027-A. L. F.	0·33	....

Though the variability in the lint index is greater than has generally been realized, yet it seems clear that the strains with a high amount of lint per seed maintain their relative positions in different years, and that hence this character is hereditary. The following table shows how this relative position has been kept up in four successive seasons of strains with markedly different characters.

Strain	Lint index			
	1918–19	1919–20	1920–21	1921–22
	grm.	grm.	grm.	grm.
B-1	2·9	2·7	2·9 2·7	2·8 2·9
C-1	2·8	2·4	2·7 3·0	2·9 2·7
1-A Long Boll	4·0	3·8	3·9 4·2	4·4 4·3 4·2
1-A Cylindrical Boll	....	3·7	3·6 3·7	4·0 3·5 3·9
Selection 2	4·0	3·3	3·8 3·9	4·2 4·6
1027-A. L. F.	3·5	3·0	3·5 3·7	3·7 3·9

Though the general relative position remains constant the variation in the strains is by no means equal. Thus in "1029-A.L.F." and in "Selection 2" the variations are very high indeed, and the reduction in the lint index in the year with late rainfall (1919–20) was much greater than with other types.

III. THE CORRELATION OF CERTAIN CHARACTERS IN *BROACH DESHI* COTTON.

We have discussed in some detail the variability of some of the more important characters in pure strains of *broach deshi* cotton. It remains to see whether the development of some of these or other characters is correlated with that of others. The matter is of considerable importance in the breeding of useful cottons, as by this means it can be ascertained whether or not any particular combination of qualities is likely to be obtainable. Further, an easily observable character may possibly be used to judge the development of another which can less easily be determined, if they are found to be closely correlated.

(*a*) Correlation between length of petioles and greatest breadth of the leaf.

It is a matter of some importance, especially in a region of heavier rains than are usual in cotton growing areas, that the leaf blade should not be too large and wide. In American cottons, its importance is recognized, for Bennett[1] has stated that " the largest leaves should not be wider than five or six inches across, at right angles to the midrib, because if otherwise, it prevents the drying of the lower bolls, and where the plant is large, it causes the loss of bolls by rotting."

The actual measurements on which the present correlation study is based were made on measurements of the third, fourth, fifth and sixth leaves from the base of the main stem, and involved measurements of 1,129 leaves of *broach deshi* types and 397 leaves of *goghari* types. The frequency variation of these characters is given in the accompanying statements. (Appendices I and II). The results in actual co-efficients were as follows :—

Leaf number	Co-efficient of correlation	Probable error
	Broach deshi type	
(1) Third from base	+ 0·71	± 0·02
(2) Fourth " "	+ 0·75	± 0·017
(3) Fifth " "	+ 0·75	± 0·017
(4) Sixth " "	+ 0·83	± 0·014
	Goghari type	
(1) Third from base	+ 0·69	± 0·029
(2) Fourth " "	+ 0·75	± 0·025
(3) Fifth " "	+ 0·69	± 0·032

[1] Bennett. *U. S. Dept., Agri. Farmers' Bull.* No. 314, p. 15 (1908).

These figures show that there is a strong positive correlation between the two measurements quoted.

(*b*) Correlation between the weight of the cotton seed and the size of the boll.

It has been established already that there is a relation between the size of a cotton boll and the weight of the *kapas* per boll, and also that the diameter of the boll very largely determines its size if the number of cells remains the same. Now the weight of *kapas* per boll may depend (1) on the number of seeds, (2) on the weight of each individual seed, and (3) on the weight of lint per seed. It will be shown later that there is a positive correlation between the weight of seed and weight of lint attached to it. Therefore if it is proved that the number of seeds per boll is not less when the bolls are smaller (that is, when the boll diameter is less and the width of each cell is less), a positive correlation between size of the boll and weight of the cotton seed is established.

Such a correlation has been established by Hudson[2] in American cotton. The following figures show from three strains of *broach deshi* cotton and from the three successive years, the number of seeds per hundred bolls, and the weight of *kapas* in the same bolls.

Strain	1919–20		1920–21		1921–22	
	Seeds in 100 bolls	Weight of *kapas* in 100 bolls	Seeds in 100 bolls	Weight of *kapas* in 100 bolls	Seeds in 100 bolls	Weight of *kapas* in 100 bolls
		grm.		grm.		grm.
C–1	1937	165·2	1972	169·6	2048	191·8
Selection 2 ..	1877	198·9	1775	204·7	1964	231·6
1–A Cylindrical Boll	1945	203·3	1956	203·3	2026	224·6

These figures show several points. In the first place, the strain in which the seeds are smaller ("C-1") does not contain less seeds than either of the other two. The number of seeds varies greatly in "Selection 2"; because

[2] *Arkansas Agri. Expt. Stn. Bull.*, No. 168 (1920).

here in some seasons as in 1920-21 the fertilization (that is the relation of ovules to seeds) is very low.

In "C-1," in spite of the full number of seeds, the weight of the *kapas* is the lowest, and if it is proved that this strain has the smallest bolls, it will prove that a small seed is associated with a small size of boll. The actual figures of measurements of bolls in the three strains taken for observation were as follows :—

Strain	Greatest width of cells of boll			Greatest diameter of bolls
	1919–20	1920–21	1921–22	1921–22
	mm.	mm.	mm.	mm.
C-1	20	20	20	24
Selection 2	22	22	22	26
1-A Cylindrical Boll	22	21	21	25

It would appear, therefore, judging by the strains studied that in *broach deshi* cotton increase in size of the bolls does usually indicate an increase in the size of the seeds, and not an increase in their number.

(c) Correlation between the weight of the cotton seed and the weight of the lint on the seed.

It is well known that this correlation does not exist universally among types of cotton, and there are numerous species and varieties of cotton where the seeds are large and the amount of lint small, and *vice versâ*. But within a strain this may happen and if so will be a very important point in judging the variations in the produce in different periods of a season or of several seasons. Balls, working with Egyptian cotton, Harland with Sea Island cotton, and Hilson with Cambodia cotton, have all claimed a positive correlation in these characters.

The results which the author has obtained show that a distinct positive correlation exists in the strains of *broach deshi* cotton. The following correlation tables for two of the strains illustrate the relationship.

(*i*) *Strain* " 1-*A Cylindrical Boll* " (103 *plants examined*).

Weight of seed in mg.	Frequency of weight of lint per seed			
	31 to 35 mg.	35 to 39 mg.	39 to 43 mg.	43 to 47 mg.
	plants	plants	plants	plants
53 to 57	9	13	1	1
57 to 61	7	26	11	1
61 to 65	2	12	13	3
65 to 69	..	1	..	3
Total ..	18	52	25	8

(*ii*) *Strain* " 1027-*A.L.F.*" 80 *plants examined.*

Weight of seed in mg.	Frequency of weight of lint per seed				
	30 to 34 mg.	34 to 38 mg.	38 to 42 mg.	42 to 46 mg.	46 to 50 mg.
	plants	plants	plants	plants	plants
58 to 62	1	1	..	..	..
62 to 66	1	1	..	..	..
66 to 70	1	7	3	..	..
70 to 74	..	1	10	..	..
74 to 78	..	2	18	12	..
78 to 82	..	..	16	5	0
82 to 86	..	..	..	..	1
Total ..	3	12	47	17	1

From these figures the following relationships will be seen to exist.

	1–A Cylindrical Boll	1027-A. L. F.
	mg.	mg.
Mean seed weight	59·5	74·7
Mean lint weight per seed	37·9	40·0
Correlation co-efficient	+ 0·46	+ 0·56
Probable error of correlation co-efficient ..	± 0·05	± 0·05

The correlation is significant but not very close, and seems much less than that claimed by the workers named above. But in the present variety

of cotton, even between the produce of different bolls on the same plant, the correlation seems very variable and does not always appear to be very high. The figures for six of the strains studied are as follows. The variation frequency is given in Appendix III.

Strain	Mean seed weight	Mean lint weight per seed	Correlation co-efficient	Probable error
B-1	56·9	30·4	+ 0·40	± 0·08
C-1	52·0	27·9	+ 0·59	± 0·06
1–A Cylindrical Boll	65·5	40·5	+ 0·47	± 0·08
Selection 2	62·6	44·6	+ 0·80	± 0·04
1027-A. L. F.	62·7	38·9	+ 0·58	± 0·08
1 –A Long Boll	62·8	42·9	+ 0·82	± 0·04

(*d*) Correlation between the weight of the cotton seed and the length of the staple in heavy seeded strains.

The length of the staple has been taken as that of the lint hairs on the middle of the seed, and for greater security the relationship suggested was determined from the produce of single plants. The frequency of variation is given in Appendix IV.

The following figures may be interesting in this connection as showing the co-efficient of variability of the seed weight and the lint weight and lint length from boll to boll *on a single plant.*

Strain	Co-efficient of variability		
	Seed weight	Lint weight	Lint length
B-1	7·2	9·6	5·0
C-1	11·7	14·0	4·4
1027-A. L. F.	9·9	12·5	4·5
1–A Cylindrical Boll	10·1	10·1	5·3
1–A Long Boll	12·9	17·0	8·2
Selection 2	10·8	11·2	8·2

On the whole, therefore, the lint length was considerably less variable than that of the seed weight and lint weight per seed.

The results were as follows :—

Strain	Mean length of staple	Correlation co-efficient	Probable error of correlation co-efficient
	cm.		
1027-A. L. F.	2·9	+ 0·70	± 0·052
1-A Cylindrical Boll	2·6	+ 0·46	± 0·082
Selection 2	2·4	+ 0·61	± 0·073
1-A Long Boll	2·5	+ 0·68	± 0·071
B-1	2·3	+ 0·25	± 0·089
C-1	2·4	+ 0·29	± 0·089

In the light seeded strains (" B-1 " and " C-1 ") the correlation is small and is certainly not significant. In the others it is more marked, but except perhaps in strain " 1027-A.L.F." it is certainly not close.

IV. DESCRIPTION OF CERTAIN PURE LINE STRAINS OF *BROACH DESHI* COTTON.

The characters which differentiate the *broach deshi* variety of *Gossypium herbaceum* from the *goghari* variety of the same species have been described in the author's previous Memoir.[1] But in the types which have the characteristics of *broach deshi,* there are many strains which differ from one another by characters which are of direct or indirect economic importance, and which breed true. These strains are, however, not merely mixed. They have crossed with one another to an enormous extent and few, if any, of a pure character now exist in cultivation. Any attempt to make a permanent improvement in the character of the cotton grown, or even to fix a type which shall approach as near as may be to the ideal for the South Gujarat cotton area must be commenced evidently by the isolation of such pure strains, breeding true, which can be used as the basis for establishing types, or of making crosses with other varieties of cotton.

[1] *Mem. Agri. Dept. India, Bot. Ser.*, XI, No. 4, p. 84

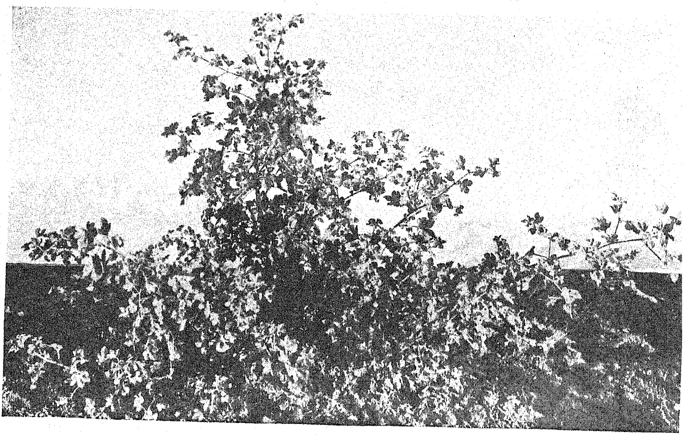


Fig. 1. Broach Deshi Strain "B-1"
(Leaves dark green and smaller and broader than those of "C-1")

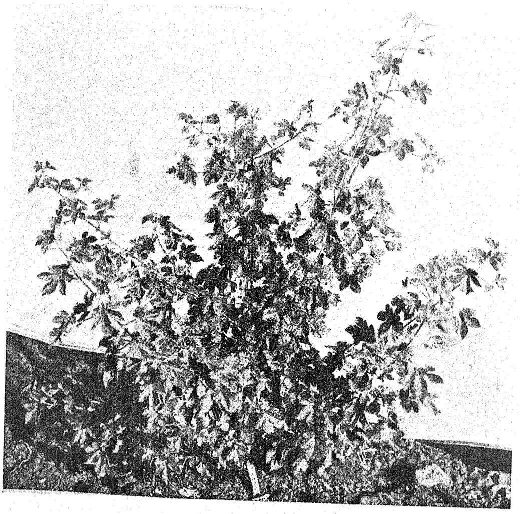
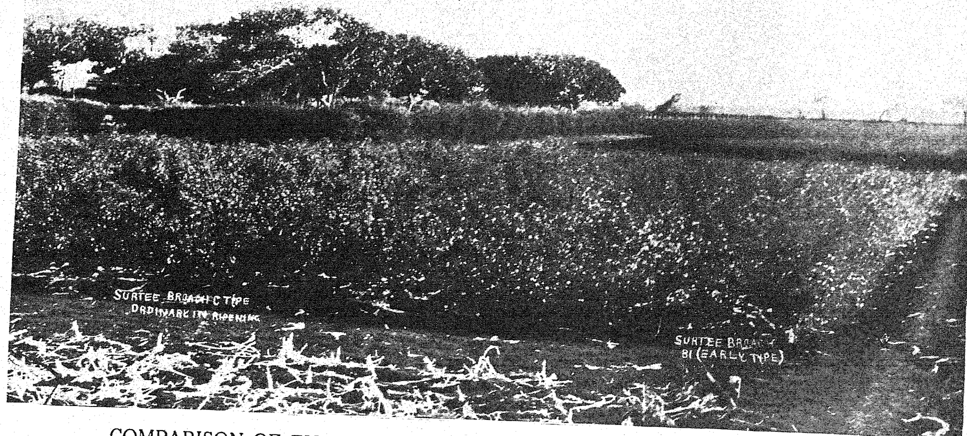


Fig. 2. Broach Deshi strain "C-1."
(Leaves light green in colour and deeply sected as to have a constriction at the base of the lobe)



COMPARISON OF THE HABIT OF RIPENING OF BROACH DESHI STRAINS.
"B-1" (RIGHT) AND "C 1" (LEFT).

It is now proposed to describe six such pure strains, which have been isolated, in order to indicate the range of variation which exists in *broach deshi* cotton, and also the fluctuation of characters within the strain itself. The strains described have been in pure line culture since 1918-19 or 1919-20.

Strain "B-1."

The first of these strains which has been termed "B-1" is derived from a selection originally made in 1916-17 on the basis of the size and shape of the boll. In the case of the parent of the present strain the boll was round but slightly pointed at the top. The progeny of the original plant varied much in 1917-18, and it was obvious that a good deal of splitting had occurred. From 1918-19, the plants secured from self-fertilized parents were uniform, and from 1919-20 the strain has been maintained from protected flowers. It has bred absolutely true since then with the following characteristics :—

(1) The plants of this strain are of a bushy character, and bear a number of monopodia varying from none to ten. The most frequent number of monopodia in all the years from 1919-20 to 1921-22 has been six. The leaves of this strain are characterized by a specially dark green colour, and by being smaller and broader than in other strains. This character of the leaf can be distinguished when the plants have grown for nearly two months and is shown in Plate II. Fig. 1.

(2) The most frequent node from which the first primary fruiting branch arises was the 19th (counting from the base) in 1919-20, the 12th or 13th in 1920-21, and the 18th or 19th in 1921-22.

(3) The strain under consideration is the earliest in ripening among all the types examined, and it is for this character that it has been maintained in our collections. The habit can be best shown by the proportion of the total yield given which was harvested in the first picking. This amounted to 71 per cent. in 1918-19, when another strain ("C-1") grown beside it only gave 45 per cent. Similarly in 1919-20, 60 per cent. of the yield was produced in the first picking, while the adjoining plants of "C-1" only gave 36 per cent. In comparison with the same strain in 1920-21, it was a fortnight earlier (Plate III). This characteristic is due to the fact of its producing a large number of fruiting branches from accessory buds both on the main stem and on the monopodia. It is, consequently, not a very leafy variety. It sheds a very large proportion of its flower buds and flowers and is a low yielding strain.

(4) The average measurements of the bolls, in centimeters, were as follows in three separate years :—

	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Greatest diameter	..	..	2·4
Length from gland to tip	2·9	2·9	2·9
Greatest width of one cell	2·0	2·0	2·0
Width of cell 7 mm. from tip	..	1·1	1·1

(5) The average weight of each seed (average of 2,000 seeds in each case) is as follows :—

	mg.
1918–19	55·1
1919–20	54·0
1920–21	52·1
1921–22	53·9

The seed is, hence, lighter than in most of the other strains studied. In 1921-22, the variability of the seed weight from boll to boll on a single plant was studied, and it was found to be less than in any other strain, the co-efficient of variability being 7·2.

(6) The average weight of lint per 100 seeds (lint index) in four successive years is as follows :—

	grm.
1918–19	2·9
1919–20	2·7
1920–21	2·8
1921–22	2·9

In 1921-22, the variability of the lint index from boll to boll on a single plant was studied, and it was found to be less than in any other strain, the co-efficient of variability being 9·6.

Where the seed weight is varying, the lint index forms a better means of comparison between the proportion of lint to seed in different strains and in different seasons than the ginning percentage. This last figure was as follows, however, in the four years quoted, 1918-19, 34·8 ; 1919-20, 33·1 ; 1920-21, 35·5 ; 1921-22, 34·9.

(7) The length of staple is practically the same as that of the average of *broach deshi* cotton in cultivation. In 1921-22, the actual measurements

at the tip, middle and base were made on 180 seeds, with the following results.

	Average length of staple
	cm.
Lint on tip of seed	1·9
Lint on middle of seed	2·4
Lint on base of seed	2·3

The variation from the mean (*a*) at the tip was 15·7 per cent. below, (*b*) at the middle was 10·5 per cent. above, and (*c*) at the base 5·3 per cent. above. The co-efficient of variability from boll to boll on a single plant in 1921-22 was 5·0.

The lint on the middle of the seed varied as follows in 1921-22 as determined from 180 measurements on different seeds.

Number of measurements made	180
	Per cent.
Staple of 1·7 to 1·9 cm.	3
„ 1·9 to 2·1 „	7
„ 2·1 to 2·3 „	14
„ 2·3 to 2·5 „	32
„ 2·5 to 2·7 „	37
„ 2·7 to 2·9 „	7

The variation is illustrated in Fig. 3 below.

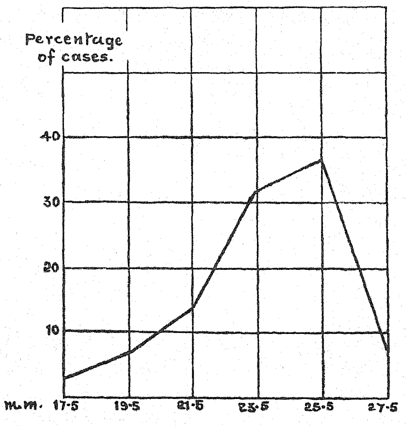


FIG. 3. Variation in staple in strain "B-1" in 1921-22.

The lint from this strain was examined by the Millowners' Association, Bombay, 1921-22, with the following results :—

" Value of lint per candy of 784 lb. is rupees eighty more than *fully good broach*. The lint is strict superfine, with good colour and nice fibre, but not so long."

STRAIN " C-1."

In the same year as the strain previously described, that now under consideration was selected at Surat. In 1918-19 it was found to be quite pure and since then it has bred absolutely true to type. Since 1919 it has been maintained as a pure line. The strain has the following characters.

(1) The plants of this strain are the least bushy of all the selected types of *broach deshi* cotton that have been isolated. The number of monopodia varies from one to nine, but the most frequent number in 1919-20 was 5, in 1920-21 was 5 to 6, and in 1921-22 was 5.

The leaves of the plants of this strain are light green in colour and are longer and more deeply lobed than those of other types. There is also a marked constriction at the base of each lobe. These characteristics are shown in Plate II. Fig. 2.

The first primary fruiting branch arises from a lower node than in any other strain. The most frequent node at which this occurs has been the 17th in 1919-20, the 13th in 1920-21 and the 17th or 18th in 1921-22.

The special feature of this strain is that the internodes on the main stem (from the thirtieth upward) are long and hence the plants have an open habit of growth. This is shown in the following table, where other strains are compared with it as grown in 1921-22.

	Length of the main stem from 30th to 35th node inches
1-A Cylindrical Boll	7·3
1-A Long Boll	7·2
B-1	7·0
C-1	8·4
Selection 2	7·6

The axillary vegetative branches behave similarly.

As a result the plants are less attacked by bollworm in the early stages. A greater percentage of success in flower buds is attained, therefore, in the early part of the season (see page 201). The percentage of success of bolls from flowers is high.

(3) The bolls of this strain are long, narrow, and tapering. The average measurements of the bolls, in centimeters, were as follows in three separate years :—

	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Greatest diameter	..	..	2·3
Length from gland to tip	3·1	2·9	3·0
Greatest width of one cell	2·0	2·0	2·0
Width of cell 7 mm. from tip	..	1·0	1·0

This strain produces a large number of four-celled bolls.

(4) The average weight per seed is as follows :—

	mg.
1918–19	50·4
1919–20	50·5
1920–21	53·3
1921–22	51·4

The seed is hence lighter than in any other of our strains, even lighter than in "B-1." In 1921-22, the variability of the seed weight from boll to boll of a single plant was greater than in the strain previously described, the co-efficient of variability being 11·7.

(5) The average weight of lint per 100 seeds (lint index) in four successive years is as follows :—

	grm.
1918–19	2·9
1919–20	2·4
1920–21	2·8
1921–22	2·8

In 1921-22, the variability of the lint index from boll to boll on a single plant was found to be higher than in most of the strains. The co-efficient of variability was 14·0.

The ginning percentage may also be quoted for each of the four seasons. It is shown as follows :—

	Per cent.
1918–19	36·3
1919–20	32·5
1920–21	34·5
1921–22	35.2

(6) The lint gave the following average measurements in different parts of the seeds in 1920-21 and 1921-22.

	Length of staple	
	1920–21	1921–22
	cm.	cm.
Lint on tip of seed	1·7	2·0
Lint on middle of seed	2·0	2·5
Lint on base of seed	2·0	2·4

The variations from the mean, taking the two years together, (*a*) at the tip was 11·7 per cent. below, (*b*) at the middle was 6·9 per cent. above, and (*c*)

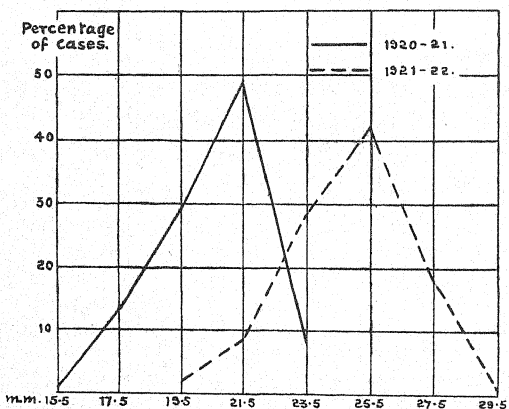


Fig. 4. Variation in staple in strain "C-1" in 1920-21 and 1921-22.

at the base was 4·7 per cent. above. The co-efficient of variability from boll to boll on a single plant in 1921-22 was 4·4.

The lint on the middle of the seed varied as follows, as determined from 100 measurements in 1920-21 and 174 in 1921-22.

	1920–21	1921–22
Number of measurements made ..	100	174
Staple of 1·5 to 1·69 cm.	1	..
„ 1·7 to 1·89 „	13	..
„ 1·9 to 2·09 „	29	2
„ 2·1 to 2·29 „	49	9
„ 2·3 to 2·49 „	8	28
„ 2·5 to 2·69 „	..	42
„ 2·7 to 2·89 „	..	18
„ 2·9 to 3·09 „	..	1

The co-efficient of variability of the lint measurements from seed to seed was, therefore, 7·8 in 1920-21 and 6·9 in 1921-22.

The lint from this strain was examined by the Millowners' Association, Bombay, with the following results :—

Year	Value of lint per candy of 784 lb.	
	Fine *broach deshi.*	"C-1"
	Rs.	Rs.
1920–21	310	315
1921–22	570	600

On the whole, therefore, this strain may be described as a tall growing type with a sparse habit, with average yielding capacity. The flower buds are less attacked by bollworm than in most other strains. It has been maintained in our collections on these accounts.

"1-A Cylindrical Boll."

This strain was originally selected in 1917-18. It was an attempt to select for a character easily recognizable in the field. This would enable the

roguing of a crop to be easily accomplished. It was found to be pure in 1919-20, and has been propagated since that time from protected flowers. Since 1921-22 it has been grown on a large scale in the Broach District. The progeny from protected flowers breed absolutely true.

(1) The plants of this strain are the bushiest of all the selected types of *broach deshi* cotton that have been isolated. The number of monopodia per plant varies from 4 to 12, but the most frequent number in 1919-20 was 6, in 1920-21 was 7 to 9, and in 1921-22 was 8 to 9. This great development of monopodia leads to a high yield in most of the seasons in Southern Gujarat. The leaves of this strain are more hairy and hence are comparatively little attacked by sucking insects such as jassids.

(2) The first primary fruiting branch arises at a higher node than with other selections, and also at a greater height on the main stem. The most frequent node at which this occurs has been the 19th in 1919–20, the 15th in 1920–21, and the 20th in 1921–22.

The internodes on the lower part of the main stem (up to the sixteenth node) are longer in this strain than in any of the others. In most seasons the amount of flower-bud shedding is less than with other strains, unless there be rain at the time of flowering, when it is more affected than the type last described. The stigma of the flower in this type is more exserted than in any other type. The number of anthers is smaller.

(3) The bolls of this strain are cylindrical, that is to say, they taper only slightly. The average measurements of the bolls, in centimeters, were as follows in three separate years.

	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Greatest diameter ..	..	..	2·5
Length from gland to tip ..	3·2	3·2	3·1
Greatest width of one cell ..	2·2	2·1	2·1
Width of cell, 7 mm. from tip .	..	1·0	1·0

This strain produces the least number of four-celled bolls among all the selections.

(4) The average weight per seed is as follows :—

					mg.
1919–20	..	..	..	..	59·1
1920–21	..	..	..	..	56·3
1921–22	..	..	..	..	63·7

The seed is, hence, heavier than in the two strains previously described.

The co-efficient of variability of the seed weight from boll to boll of a single plant in 1921–22 was 10·3. The variability of the average seed weight from plant to plant in 1919-20 is less than the above, the co-efficient of variability being 5·4.

(5) The average weight of the lint per 100 seeds (lint index) in three successive years is as follows :—

	grm.
1919–20	3·6
1920–21	3·6
1921–22	3·8

This character is more constant from season to season than in any other of the selected strains.

In 1921–22, the variability of the lint index from boll to boll on a single plant was determined and the co-efficient of variability was found to be 10·1. The variability of the average lint index from plant to plant in 1919–20 is less than the above, the co-efficient of variability being 8·6.

The ginning percentage may also be quoted for each of the last three seasons.

	Per cent.
1919–20	36·1
1920–21	39·4
1921–22	37·7

When the strain is transferred from Surat to Broach, that is to say to a somewhat earlier and drier climate, the seed weight tends to increase more than the lint weight and hence the ginning percentage tends to decrease.

(6) The lint gave the following average measurements in different parts of the seeds in 1919-20, 1920-21, and 1921-22.

	Length of staple		
	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Lint on tip of seed ..	2·2	1·7	2·1
Lint on middle of seed ..	2·5	2·2	2·6
Lint on base of seed ..	2·4	2·1	2·6

The variation from the mean, taking the years together, (*a*) at the tip was 12·6 per cent. below, (*b*) at the middle was 7·9 per cent. above, and (*c*)

at the base was 5·2 per cent. above. The co-efficient of variability from boll to boll on a single plant in 1921–22 was 5·3.

The lint on the middle of the seed varied as follows, as determined from 100 measurements in each case.

	1919–20	1920–21	1921–22
Number of measurements ..	100	100	100
Staple of 1·6 to 1·79 cm. ..	..	1	..
„ 1·8 to 1·99 „ ..	1	13	..
„ 2·0 to 2·19 „ ..	4	28	1
„ 2·2 to 2·39 „ ..	16	28	6
„ 2·4 to 2·59 „ ..	39	27	22
„ 2·6 to 2·79 „ ..	27	3	46
„ 2·8 to 2·99 „ ..	12	..	20
„ 3·0 to 3·19 „ ..	1	..	5

The co-efficient of variability of the lint measurements from seed to seed was, therefore, 8·8 in 1919–20, 10·0 in 1920–21 and 7·2 in 1921–22.

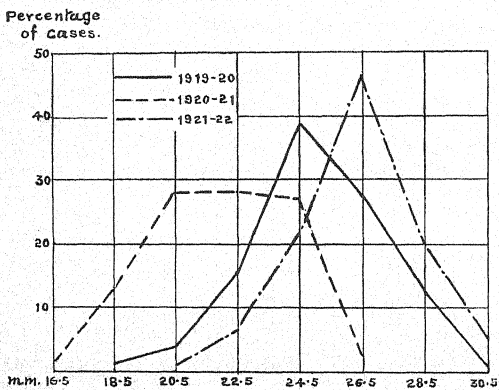


FIG. 5. Variation in staple in strain "I-A Cylindrical Boll" in 1919-20, 1920-21 and 1921-22.

The lint from this strain was examined by the Millowners' Association, Bombay, with the following results :—

Year	Value of lint per candy of 784 lb.	
	Fine *broach deshi*	"1-A Cylindrical Boll"
	Rs.	Rs.
1920–21 ..	310	325
1921–22 ..	570	640

This strain is particularly valuable on account of its high and constant yield, its high ginning percentage, and good staple. In this last quality it stands only second to "1027-A. L. F." a strain selected from the Navsari area.

"1-A Long Boll."

This strain was originally selected in 1916–17 with the object mentioned for the strain last described.

It was found to be pure in 1919–20 and has been propogated pure since that time from protected flowers. Since 1921–22, it has been grown on a large scale in the Surat District. The progeny from protected flowers breeds absolutely true.

(1) The plants of this strain are of a bushy character and have a number of monopodia varying from five to eleven. The most frequent number in 1920–21 was seven and in 1921-22 was seven to eight.

(2) The most frequent node from which the first primary fruiting branch arises was fourteenth in 1920–21 and nineteenth to twentieth in 1921–22.

The internodes of the main stem are shorter than in the strain last described. The flowering habit is late and the number of flowers formed in the later part of the flowering period is large. Due to this reason the produce from bolls is particularly free from disease and is superior in "class." The flowers of this strain open more widely than in any other strain.

(3) The bolls of this strain are longer and narrower at the tip than those of other types. The size is also larger than that of other strains. The

average measurements of the bolls in centimeters were as follows in three separate years :—

	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Greatest diameter ..	..	..	2·7
Length from gland to tip ..	3·8	3·6	3·6
Greatest width of one cell ..	2·4	2·2	2·2
Width of cell 7 mm. from tip	..	0·8	0·9

This strain produces a large number of four-celled bolls. The bolls of this strain do not open so completely as do most of the *broach deshi* strains examined.

(4) The average weight per seed is as follows :—

	mg.
1919–20	59·4
1920–21	62·1
1921–22	64·3

The seed is, hence, heavier than in most of the strains.

The co-efficient of variability of the seed weight from boll to boll of a single plant in 1921–22 was 12·9.

(5) The average weight of lint per 100 seeds (lint index) in three successive years is as follows :—

	grm.
1919–20	3·8
1920–21	4·0
1921–22	4·3

In 1921–22, the variability of the lint index, from boll to boll on a single plant, was determined, and the co-efficient of variability was found to be 17·0, that is to say, it is higher than in any of the strains examined in detail.

The ginning percentage may also be quoted for each of the last three seasons.

	Per cent.
1919–20	39·2
1920–21	39·3
1921–22	40·1

Thus in the present case, the ginning percentage is more constant than the lint index owing to the proportionate increase of seed weight and lint

weight. It is higher than in any of the strains of *broach deshi* cotton examined.

(6) The lint gave the following average measurements in different parts of the seed in 1919–20, 1920–21 and 1921–22.

	Length of staple		
	1919–20	1920–21	1921–22
	mm.	mm.	mm.
Lint on tip of seed ..	2·2	2·0	2·1
Length of middle of seed ..	2·5	2·5	2·6
Lint on base of seed ..	2·3	2·4	2·6

The variation from the mean, taking the years together, (*a*) at the tip was 12·2 per cent. below, (*b*) at the middle was 7·1 per cent. above, and (*c*) at the base 4·0 per cent. above. The co-efficient of variability from boll to boll on a single plant in 1921–22 was 8·2. From year to year it is more constant than in any of the strains examined.

The lint on the middle of the seed varied as follows, as determined from 100 measurements, in each case.

	1919–20	1920–21	1921–22
Number of measurements ..	100	100	100
Staple of 1·7 to 1·89 c.m. ..	..	..	1
„ 1·9 to 2·09 „ ..	2	3	0
„ 2·1 to 2·29 „ ..	15	10	6
„ 2·3 to 2·49 „ ..	29	25	18
„ 2·5 to 2·69 „ ..	30	34	34
„ 2·7 to 2·89 „ ..	21	23	34
„ 2·9 to 3·09 „ ..	3	4	7
„ 3·1 to 3·29 „ ..	..	1	..

The co-efficient of variability of the lint measurement from seed to seed was, therefore, 9·1 in 1919–20, 9·3 in 1920–21 and 8·1 in 1921–22. The dry

season of 1920-21 had much less effect on the staple than with most of the other strains.

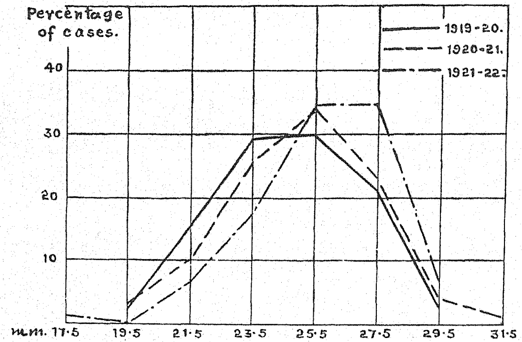


FIG. 6. Variation in staple in strain "I–A Long Boll" in 1919–20, 1920–21 and 1921–22.

The lint from this strain was examined by the Millowners' Association, Bombay, with the following results.

Year	VALUE OF LINT PER CANDY OF 784 lb.	
	Fine *broach deshi*	1-A Long Boll
	Rs.	Rs.
1920–21	310	340
1921–22	570	640

This strain is particularly valuable on account of its high yield, which is not so seriously affected as other types in dry years, its high ginning percentage and its good staple.

"SELECTION 2."

This strain was originally selected in 1914–15, with the object mentioned for "1-A Cylindrical Boll." It has proved to be pure since 1917–18, and has been propagated since 1919-20 from protected flowers.

(1) The plants of this strain are of a bushy character and have a number of monopodia varying from two to thirteen. The most frequent number in 1920–21 and in 1921–22 was seven.

(2) The most frequent node from which the first primary fruiting branch arises was fifteenth in 1920-21 and nineteenth in 1921-22. Owing to the peculiar spreading habit of the bracts, the flower buds of this strain are less attacked by bollworm than others, but if there be rain at the time of flowering, the strain is much damaged.

This strain has one specially objectionable character. In a year like that of 1920-21, in which the flowering is early, this has the least normal fertility, that is to say, the average number of seeds formed in comparison with ovules is very low. The results are as follows :—

Strain	1920–21	1921–22
	Percentage of seed to ovules	Percentage of seed to ovules
Selection 2	75·2	91·7
1–A Long Boll ..	89·0	96·7
1–A Cylindrical Boll ..	89·1	93·3
1027–A. L. F.	88·0	94·5
C–1	95·7	94·8

(3) The bolls of this strain are cylindrical, that is to say, they taper very slightly. The average measurements of the bolls in centimeters were as follows :—

	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Greatest diameter ..	..	..	2·6
Length of gland to tip ..	3·2	3·1	3·1
Greatest width of one cell ..	2·2	2·2	2·2
Width 7 mm. from tip ..	..	1·0	1·0

It produces a slightly higher number of four-celled bolls than the strain "1-A Cylindrical Boll."

(4) The average weight per seed is as follows :—

	mg.
1917–18	61·9
1918–19	60·9
1919–20	60·3
1920–21	62·5
1921–22	64·2

The weight of seed is almost similar to that of "1-A Long Boll." The co-efficient of variability of the seed weight from boll to boll of a single plant in 1921–22 was 10·8.

(5) The average weight of lint per 100 seeds (lint index) is as follows :—

					grm.
1917–18	..	..	..	..	3·6
1918–19	..	..	..	..	4·0
1919–20	..	..	..	..	3·3
1920–21	..	..	..	..	3·8
1921–22	..	..	..	..	4·4

This varies from season to season more than in any of the other strains examined. The co-efficient of variability of the lint index from boll to boll on a single plant in 1921–22 was 11·2.

The ginning percentage may also be quoted as follows :—

				Ginning percentage
1917–18	..	..	..	37·1
1918–19	..	..	..	40·0
1919–20	..	..	..	35·4
1920–21	..	..	..	38·1
1921–22	..	..	..	40·7

Again in the strain under discussion, the ginning percentage proves to be more constant than the lint index, and this is even more strikingly shown than in the last strain described. It is due to the proportionate increase of seed weight and lint weight.

(6) The lint gave the following average measurements in different parts of the seed in 1920–21 and 1921–22.

	Length of staple	
	1920–21	1921–22
Lint on tip of seed	2·0	2·1
Lint on middle of seed	2·4	2·5
Lint on base of seed	2·3	2·4

The variations from the mean, taking the years together, (*a*) at the tip was 11·2 per cent. below, (*b*) at the middle was 7 per cent. above, and (*c*) at the base was 3 per cent. above.

The co-efficient of variability from boll to boll on a single plant in 1921–22 was 8·2.

The lint on the middle of the seed varied as follows, as determined from 100 measurements in each case.

	1920–21	1921–22
Staple of 1·7 to 1·8 cm.	..	1
„ 1·9 to 2·0 „	2	3
„ 2·1 to 2·2 „	16	14
„ 2·3 to 2·4 „	38	31
„ 2·5 to 2·6 „	35	32
„ 2·7 to 2·8 „	9	14
„ 2·9 to 3·0 „	..	5
„ 3·1 to 3·2 „	..	..

The co-efficient of variability of the lint measurements from seed to seed was, therefore, 7·5 in 1920–21 and 9·9 in 1921–22.

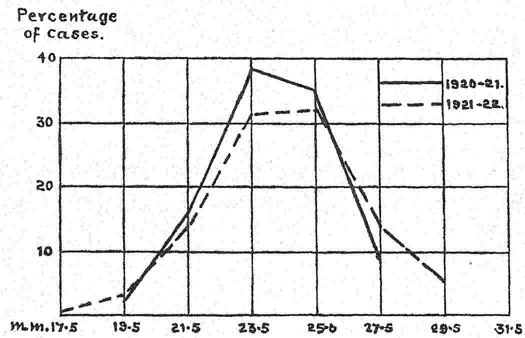


FIG. 7. Variation in staple in strain "Selection 2" in 1920–21 and 1921–22.

The lint from this strain was examined by the Millowners' Association, Bombay, with the following results :—

Year	Value of lint per candy of 784 lb.	
	Fine *broach deshi*	Selection 2
	Rs.	Rs.
1920–21	310	315

The strain is maintained amongst our collection on account of the peculiar spreading character of the bracts.

"1027-A. L. F."

This strain was originally selected in 1917-18* from the best type of cotton cultivated in Southern Gujarat. The shape of the boll also enables it to be easily identified in the field. It was found pure in 1919–20 and has been propagated since that time from protected flowers. Since 1921–22 it has been grown on a large scale in the south of the Surat District.

(1) The plants of this strain are of a bushy character and have a number of monopodia varying from 3 to 11. The most frequent number in 1920-21 and 1921–22 was 7 to 8.

(2) The most frequent node from which the first primary fruiting branch arises was fourteen in 1920–21 and nineteen in 1921–22.

The leaves of this strain are particularly dark green and leathery just when the cold weather sets in. This character can be definitely recognized for a month. After this time, in all the strains, the leaves present a similar dark green colour.

The colour of the pollen is of deeper pink than in any other strain.

The vigour of the branches, vegetative as well as fruiting, expressed by growth in nodes is lower than in the other strains described. A large number of abnormalities of leaves and involucres is found in those seasons in which the vegetative growth is great. This results in higher shedding of flower buds in those years.

(3) The bolls of this strain are almost similar to those of "1-A Long Boll," that is to say, they are long and tapering. The average measurements of the bolls in centimeters were as follows in three successive years :—

...	1919–20	1920–21	1921–22
	cm.	cm.	cm.
Greatest diameter	..	..	2·7
Length from gland to tip	3·6	3·4	3·4
Greatest width of one cell	2·2	2·1	2·2
Width of cell 7 mm. from tip	..	1·0	1·0

The opening of bolls is also similar to that of "1-A Long Boll."

* The name had been previously applied to a mixed type maintained from about ten years earlier.

(4) The average weight per seed is as follows :—

	mg.
1919–20	63·2
1920–21	65·9
1921–22	64·3

The seed is heavier than in any of the other strains examined. The co-efficient of variability of the seed weight from boll to boll of a single plant in 1921–22 was 9·9. In the same year the co-efficient of variability of the average seed weight from plant to plant was only 6·7.

The average weight of lint per 100 seeds (lint index) in three successive years was as follows :—

	grm.
1919–20	3·0
1920–21	3·6
1921–22	3·8

(5) This character is very varying from season to season, and is also low in comparison with seed weight. In 1921–22, the variability of the lint index from boll to boll on a single plant was determined and the co-efficient of variability was found to be 12·5. The variability of the average lint index from plant to plant in 1921–22 was 7·1.

The ginning percentage may also be quoted for each of the last three seasons :—

	Per cent.
1919–20	32·2
1920–21	35·3
1921–22	35·1

Thus it is little higher than is usually found is the mixture of unselected strains commonly grown in the district.

(6) The lint gave the following average measurements in different parts of the seed in 1920-21 and 1921-22.

	Length of staple	
	1920–21	1921–22
	cm.	cm.
Lint on tip of seed	2·0	2·4
Lint on middle of seed	2·5	2·9
Lint on base of seed	2·3	2·8

The variation for the mean, taking the years together, (*a*) at the tip was 12·9 per cent. below, (*b*) at the middle 8·3 per cent. above, and (*c*) at the base 2·5 per cent. above. The co-efficient of variability from boll to boll on a single plant in 1921-22 was 4·5.

The lint on the middle of the seed varied as follows :—

	1920–21	1921–22
Number of measurements	100	1,324
	per cent.	per cent.
Staple of 1·9 to 2·0 cm.	4	..
„ 2·1 to 2·2 „	8	1
„ 2·3 to 2·4 „	32	4
„ 2·5 to 2·6 „	30	17
„ 2·7 to 2·8 „	25	35
„ 2·9 to 3·0 „	1	28
„ 3·1 to 3·2 „	..	13
„ 3·3 to 3·4 „	..	2

The co-efficient of variability of the lint measurements from seed to seed was therefore 8·7 in 1920-21 and 8·2 in 1921-22.

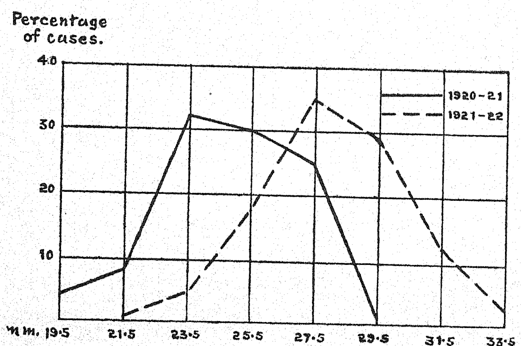


FIG. 8. Variation in staple in strain "1027–A. L. F." in 1920–21 and 1921–22.

The lint from this strain was examined by the Millowners' Association, Bombay, with the following results.

Year	Value of lint per candy of 784 lb.	
	Fine *broach deshi*	1027-A.L.F.
	Rs.	Rs.
1920-21	310	335
1921-22	570	640

This strain is particularly valuable on account of its long silky staple with creamy white colour.

Comparison of strains of *broach deshi* cotton.

From the description of the six strains, which, out of a very large number of selections made, have been maintained, it will be seen that each has some special quality, cultural or otherwise, which gives it value. We may now summarize the commercial qualities of these types, in respect to the yield per acre, the ginning percentage of the *kapas*, the length of staple of the lint, and the market value of the lint. The results are based on figures obtained from the average of the produce of three years' cultivation in comparable plots.

Strain	Yield of *kapas* per acre	Yield of lint per acre	Ginning percentage	Value per candy	Value of lint per acre	Average length of staple. Middle of seed
	lb.	lb.		Rs.**	Rs.	cm.
B-1	*	..	34·5	467	..	2·4(a)
C-1	*	..	34·1	458	..	2·25†
1-A Long Boll ..	640	248	38·2	490	155·0	2·52
1-A Cylindrical Boll ..	718‡	278‡	38·7	482	170·9‡	2·43
Selection 2 ..	485	185	38·2	..	..	2·45†
1027 A. L. F. ..	586	206	35·2	488	128·2	2·7†
Average of local *broach deshi* ..	502	171	34·1	(Surat-440) (Navsari—458)	95·9	2·2

* Figures comparable with the others are not in hand for these strains, as they were grown in different areas. "C-1" in 1920-21 and 1921-22 gave 442 lb. *kapas* per acre in land on which "1-A Long Boll" gave 478 lb. per acre. Similarly in 1919-20 when "C-1" gave 594 lb., "B-1" only 469 lb.

‡ 1919-20 and 1920-21 only, as 1921-22 was a bad year. The true average is below this figure.

† 1920-21 and 1921-22 only.

(a) 1921-22 only.

** Average of 1920-21 and 1921-22. Surat local cotton is taken at Rs. 440 per *candy*.

In the local *broach deshi* cotton at Surat (which is of course a mixture) the proportion of the seeds (average of three years) which had staple of different lengths is as follows :—

cm.	Per cent.
1·4 to 1·59	1·0
1·6 to 1·79	3·7
1·8 to 1·99	8·3
2·0 to 2·19	27·7
2·2 to 2·39	28·0
2·4 to 2·59	20·6
2·6 to 2·79	9·7
2·8 to 2·99	1·0

The variations in the staple of the local cotton are shown for each year in the attached diagram.

Spinning tests of certain of these strains ("1-A Long Boll," "1027-A. L. F.") and of the local *surat* cotton, grown at Surat under identical condi-

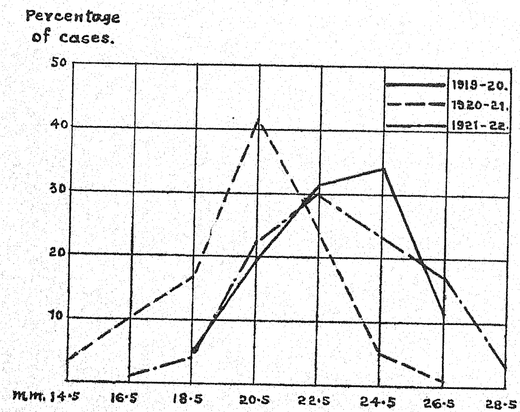


FIG. 9. Variation in staple of local *broach deshi* cotton as grown at Surat in 1919–20, 1920–21 and 1921–22.

tions, have been made for the author by the New Great Eastern Spinning and Weaving Co., Ltd., Bombay, and very sincere acknowledgments of the help given by this company are due. The lint tested was of 1921-22, and the tests were made along with the ordinary yarn drawn in the mills. The

machines, as noted by the company, should have been specially set to the staple of the cotton samples, but as there were no spare machines, this could not be done. Owing to the insufficiency of inter and roving machines, the arrangements given for attenuation in slubbing was high, and thus higher counts could not be worked. The tests were made during the rainy season so that the loss is stated to be exceptionally heavy. The actual results were as under :—

Type of cotton.	Total loss up to yarn	Count of yarn spun	Test in pounds
Local Surat cotton	27	20·2	60
1-A Long Boll	22	20·1	66
1027-A. L. F.	28	20·1	71

As a result of these tests the opinion was expressed that the Surat local cotton supplied was fit up to 20's (weft). It was, however, irregular in staple. "1-A Long Boll" was fit up to 26's (weft). It was somewhat longer in staple than the *surat* local cotton and more uniform. "1027-A. L. F." was fit for 24's (warp) and 32's (weft). The relative prices per pound of yarn were 14 annas (*surat* local), 16·4 annas ("1-A Long Boll"), and 18 annas ("1027-A. L. F.").

The above tests were made on cotton grown under the author's own supervision on the Surat farm. Strain "1027-A. L. F." has, however, been grown on a large scale in the district, and the produce so grown was tested at the instance of the purchasers, Messrs. Narandas Rajaram & Co., with the following results.

	Per cent.
Blow room loss	5·5
Card room loss	1·8

"In 41's this cotton showed a test of 28 lb. with 28 turns per inch, and in 30's we obtained 53 lb. with 23 turns per inch. From the foregoing it is obvious that the cotton is exceptionally good for 30's, but it is not good enough for spinning up to finer counts. We usually require a test of about 42 lb. in 40's."

Generally, it may be stated that the type to which the above description applies ("1027-A. L. F.") is the best in staple of all our selections, while "1-A Long Boll" stands next in this respect. Both of these are now being grown in a large scale, and the farmer is rapidly displacing the local mixture of *broach deshi* strains which has hitherto been grown in the Surat District.

V. THE IDEAL TYPE OF *HERBACEUM* COTTON IN LOWER GUJARAT.

In the author's former Memoir he attempted to set out the characters which he considered as of primary importance in a type of cotton for the special conditions of Lower Gujarat. Apart from the necessity of as high a ginning percentage and as long a staple as the conditions allow, the following characters of the cotton plants were stated as of great importance in order to secure a high yield in the Lower Gujarat climate.

(1) The plants must be able to resist heavy rain when very young, that is to say, when they have less than six leaves.

(2) The plants must possess a large number of monopodia, *i.e.*, the vegetative branches formed in the lower part of the main stem.

(3) There should be the maximum development of vegetative branches on the plant.

(4) Flowering should not commence till 15th November and should be completed before the end of January.

(5) The bolls should be large and should open completely.

The importance of these points has been confirmed by the work done since the Memoir referred to was issued, but further points must now be emphasized and additional evidence with regard to those mentioned has now been collected.

(1) A STRAIN WITH LONG INTERNODES ON THE STEM IS TO BE PREFERRED.

The very great importance of the power to resist heavy rain and water logging when young has been already insisted upon. A very great factor in such resistance seems to be the rapidity with which the plants grow in height so that they may not be actually covered with water or soil when very young. In ordinary fields where the soil level varies slightly, the stem and leaves up to a height of nearly six inches are liable to get so covered in years of continuous falls of rain. At such a time, a plant with long internodes has a distinct advantage and hence a strain of this type is to be preferred.

(2) A STRAIN WITH HAIRY LEAVES IS TO BE PREFERRED.

In many parts of the world it has been considered that hairiness of the leaves is an advantage. This is probably because they are less attacked by sucking insects such as jassids, and it is certain that such plants are healthier and more vigorous than others in South Gujarat. The strain "1-A Cylindrical

Boll," is the hairiest of all the types studied, and this has the most constant yield of all of them.

(3) A strain with high development of vegetative branches is to be preferred.

This is a point which has, so far as Southern Gujarat is concerned, been previously insisted upon, but further evidence on the matter has now been collected. Among the *broach deshi* strains studied, the type which yields highest (" 1-A Cylindrical Boll ") is also that which has the greatest number of monopodia (limbs), while that on which the crop is lowest (" C-1 ") has the smallest number of limbs. Again the type " B-1 " in which the ratio of flower buds to vegetative growth is highest, owing to the habit of giving out fruiting branches from accessory buds instead of vegetative branches, gives almost the lowest yield of all (see table on page 245).

Again if the whole vegetative growth of different types is measured (in nodes), it will be found that the strains in which this is greatest will tend to give the highest yields. Under the conditions of Lower Gujarat, this usually means (unlike what is the case in other regions, notably at Dharwar) that the number of flower buds is greater as the following figures for two of our strains show.

Year	1-A Cylindrical Boll		1027-A. L. F.	
	Vegetative growth in nodes	Flower buds	Vegetative growth in nodes	Flower buds
1919-20 ..	4,318	6,464	3,430	4,736
1921-22 ..	2,594	2,343	2,276	1,998

This is very important because owing to the necessity of concentrating the flowering into a short period (see below) it is very advantageous to have a very large number of fruiting branches late in the season, each with few nodes, rather than fewer but larger fruiting branches. This is secured by increasing the vegetative growth, as the number of fruiting branches is largely proportional to the amount of such vegetative growth measured in nodes,

(4) A STRAIN IN WHICH THE PLANT HAS A TALL OPEN HABIT OF GROWTH AND IN WHICH THE BRACTS HAVE A SPREADING HABIT IS TO BE PREFERRED.

One of the very striking features of the flowering of cotton in the *broach deshi* area is its very great intensity during the time when it is going on, and the very short period out of the intense flowering portion of the season during which any large proportion of the flowers successfully produce bolls. This is very remarkable when compared with other countries. In Egyptian cotton, according to Balls, the actual flowering period has been shown to be from 15th June to 24th September, or for three and a quarter months. The full flowering period is of nine weeks. The rate of new flowers per plant rarely exceeds one per day. In Sea Island cotton, flowering starts in the ninth week of the plants' growth and lasts for eighteen to twenty-two weeks more. It comes in full flowering from the fifteenth or sixteenth week and declines from the twenty-second week. That is to say, the full flowering period is for seven weeks. In working with Pima cotton in the Salt River Valley in America King[1] has observed flowers appearing on plants which had commenced flowering 150 days previously. However, he says, the normal period of flowering is from 90 to 110 days, out of which nearly 53 per cent. of the flowers appear within the first 45 days and the number of new flowers rarely exceeds 1·5 per day.

The results of Ewing in Mississippi and Lloyd in Alabama for Upland varieties may also be compared. They have found that the length of the flowering period is from forty to eighty days. From the results of Lloyd it appears that in Upland cotton the flowering is concentrated almost like that in the *broach deshi*, that is to say, two-thirds of the flowers appear within one month. But the most important difference between the Upland varieties in America and the types of *herbaceum* here is that in the former it starts after six to seven weeks' growth of the plant and during this intense flowering period the proportion of flowers producing ripe bolls is nearly 50 per cent., while here it starts from the twelfth to the sixteenth week and the success is only 33 per cent. The long fruiting period of American cotton has been recognized by Bennett (*l. c.*) to be an important factor in enabling poor farming to produce cotton.

The flowering of *broach deshi* cotton at Surat is as follows. In 1918 the flowering period started from the fourteenth week, and the flowering abruptly declined from the seventeenth week. In 1919-20 and 1921-22 it started

[1] *U. S. Dept. Agri. Bull.* No. 1018 (1922), p. 5.

from the seventeenth and sixteenth week respectively, the plants were in full flower from the twenty-fourth week for nearly a month and then the flowering abruptly declined. In 1920-21, flowering commenced from the fifteenth week, the plants were in full flower from the twentieth week for a month, and then the flowering rapidly declined.

The intensity of flowering can be seen by the following figure with three pure strains.

Strain	Percentage of flowers opening		
	1919–20 2nd to 30th Jan.*	1920–21 6th Dec. to 2nd Jan.†	1921–22 3rd to 30th Jan *
	Per cent.	Per cent.	Per cent.
B–1	70·5	79·3	64·6
1-A Long Boll ..	63·0	72·5	65·8
1027-A. L. F. ..	67·4	83·5	64·7

* This was the twenty-fourth to the twenty-seventh week of growth and the eighth to the eleventh week of flowering.

† This was the twentieth to the twenty-third week of growth, and the sixth to the ninth week of flowering.

The intense flowering season lasts, therefore, for nearly a month during which two-thirds or more of the flowers appear. Not only this but out of this intense flowering portion of the season the time during which flowers formed produced a large proportion of bolls is still more limited even to nearly a fortnight.

The following table shows the proportion of flowers which produced ripe bolls during the various parts of the flowering season.

Weeks of flowering	Proportion of flowers producing ripe bolls					
	B-1		1-A Long Boll		1027-A. L. F.	
	1920–21	1921–22	1920–21	1921–22	1920–21	1921–22
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1st three weeks ..	40	21·5	..	15	..	57
4th week ..	79	38·5	63·5	16·5	72·5	50
5th " ..	65	55	75	32	79	45
6th " ..	49·5*	61·5	72*	56·5	69*	65·5
7th " ..	14*	58	67*	64·5	36*	70
8th " ..	3·5*	58*	38·5*	63*	18·5*	58·5*
9th " ..	3*	54*	16*	58*	8·5*	45*
10th " ..	nil.	20*	5	28·5*	·5*	14*
11th " ..	nil.	2·5*	..	4*	..	1·5*

* Represent intense flowering weeks.

It would seem that the intense concentration of flowering into a short period, and the still greater concentration of successful boll formation from flowers into a still shorter period, is one of the principal causes of the relatively low yield in this area. If anything is likely to occur which will damage the flower buds or flowers during this short period (and many such things do occur), a very large percentage of flowers will fall off, and flowers will never develop into bolls. Perhaps the most important of such things is the attack of the bollworm (*Earias* sp.) which is responsible for an enormous amount of loss at each stage. Two features are found to increase resistance to bollworm, namely, (1) a tall open habit of growth in the plant, and (2) a spreading habit of the bracts. The former is found in the strain "C-1" among the selected strains, and the latter in "Selection 2," both of which suffer less from bollworm attack, and ripen a bigger proportion of flowers to flower buds than the other strains. This is probably because a wasp (*Microbracon lefroyii*), the presence of which has been now found to be common, can more easily attack the worms as they are more exposed in such strains.

(5) A STRAIN IN WHICH THE NUMBER OF OVULES WHICH DO NOT FORM SEEDS IS LOW IS TO BE PREFERRED.

In no type of cotton do all the ovules form seeds, but the proportion which fails to do so varies very much in different countries, and with different varieties. In *kumpta* cotton, Kottur[1] estimates the loss at five per cent. In the West Indies, Harland[2] finds the loss to be 21·3 per cent. and 32·7 per cent. in three-celled and four-celled bolls respectively, while in American cotton it is variously estimated at from 10 per cent. to 25 per cent.

In *broach deshi* strains tested at Surat, this loss has varied from 3·4 to 24·8 per cent. according to the seasons and strains. The strains differ widely in this matter. "Selection 2", for example, seems to be particularly disposed to this kind of wastage, and it shows the highest loss in both 1920-21 and in 1921-22. On the other hand, the loss is much higher in 1920-21 than in 1921-22. Besides this wastage in yield the resulting cotton from such a strain as Selection 2 is undesirable, as it will give a higher percentage of blow room loss in the form of fly.

[1] *Agri. Jour. India,* XVI, pt. I, p. 52.
[2] *West Ind. Bull.* XVII, p. 148.

TABLES SHOWING CORRELATION BETWEEN LENGTH OF PETIOLE & LEAF BREADTH IN BROACH DESHI COTTON

SEE PAGE 219 OF TEXT

CORRELATION ON THE BASIS OF THE THIRD LEAF FROM THE BASE OF THE MAIN STEM

NO OF LEAVES MEASURED, 288

BREADTH OF LEAF IN C.M.

LENGTH OF PETIOLE IN C.M. / to	0.9 1.0	1.1 1.2	1.3 1.4	1.5 1.6	1.7 1.8	1.9 2.0	2.1 2.2	2.3 2.4	2.5 2.6	2.7 2.8	2.9 3.0	3.1 3.2	3.3 3.4	3.5 3.6	3.7 3.8	3.9 4.0	4.1 4.2	TOTAL
BELOW 0.5	1		2															3
0.6 0.89				1		1												2
0.9 1.09		1		3		2			1	2								9
1.1 1.29					1	3	2	2	4		3	1						16
1.3 1.49					1	5	5	4	8	6	8	6	3	1				48
1.5 1.69						1	1	7	12	17	19	11	4	1	1			74
1.7 1.89								1	6	9	10	17	5	6	3			57
1.9 2.09									3	9	6	9	9	8	3	3		50
2.1 2.29											2	1	4	8	2			17
2.3 2.49										1				5	1			7
2.5 2.69														1	1		1	3
2.9 3.0														1	1			2
TOTAL	1	1	2	4	2	12	8	14	35	44	48	45	25	51	12	3	1	288

CORRELATION ON THE BASIS OF THE FOURTH LEAF FROM THE BASE OF THE MAIN STEM

NO OF LEAVES MEASURED, 314

BREADTH OF LEAF IN C.M.

LENGTH OF PETIOLE IN C.M. / to	1.3 1.4	1.5 1.6	1.7 1.8	1.9 2.0	2.1 2.2	2.3 2.4	2.5 2.6	2.7 2.8	2.9 3.0	3.1 3.2	3.3 3.4	3.5 3.6	3.7 3.8	3.9 4.0	4.1 4.2	4.3 4.4	4.5 4.6	4.7 4.8	TOTAL
BELOW 0.5	2			1															3
0.6 0.8	1	1		1															3
0.9 1.0		1	3	3	1	2	1	1	1										13
1.1 1.2		1		4	4	4	6	7	2	2									30
1.3 1.4				1	3	7	10	10	8	4	3	1							47
1.5 1.6				1	2	7	9	15	15	13	5	10	1						78
1.7 1.8					1		2	9	15	5	10	4	3				1		50
1.9 2.0								7	7	10	5	9	3						41
2.1 2.2								1	3	4	8	7	5	3					26
2.3 2.4											5	1	3		2				11
2.5 2.6												1	2		1	1		2	7
2.7 2.8											1	1		1			2		5
TOTAL	3	3	3	11	11	20	28	50	51	38	32	34	17	4	3	1	3	2	314

CORRELATION ON THE BASIS OF THE FIFTH LEAF FROM THE BASE OF THE MAIN STEM

NO OF LEAVES MEASURED, 296

BREADTH OF LEAF IN C.M.

LENGTH OF PETIOLE IN C.M. (to)	1.1–1.2	1.3–1.4	1.5–1.6	1.7–1.8	1.9–2.0	2.1–2.2	2.3–2.4	2.5–2.6	2.7–2.8	2.9–3.0	3.1–3.2	3.3–3.4	3.5–3.6	3.7–3.8	3.9–4.0	4.1–4.2	4.3–4.4	4.5–4.6	4.7–4.8	4.9–5.0	5.1–5.2	TOTAL
BELOW 0.5	1			1																		2
0.6–0.8		1	1	3	3	1	2	1		1												13
0.9–1.0				2	2	3	4	3		1	1	1										17
1.1–1.2						2	3	2	2	3	1	1										14
1.3–1.4					1	1	5	8	7	6	1	3	2									34
1.5–1.6					2		3	11	10	12	4	4	1									47
1.7–1.8								8	10	11	7	6	7	2	3	1						55
1.9–2.0								5	4	9	5	5	11	3	1		1					44
2.1–2.2					1				1	1	1	6	3	7	2		1	2				25
2.3–2.4							1			3	1	1	5	1	1	3				1		17
2.5–2.6											1	1	2	2	3	4						13
2.7–2.8											1	1	1		5	1			1		1	11
2.9–3.0																1		1				2
3.1–3.2																1					1	2
TOTAL	1	1	1	6	9	7	18	38	34	47	23	29	32	15	15	11	2	3	1	1	2	296

CORRELATION ON THE BASIS OF THE SIXTH LEAF FROM THE BASE OF THE MAIN STEM

NO OF LEAVES MEASURED, 231

BREADTH OF LEAF IN C.M.

LENGTH OF PETIOLE IN C.M. (to)	1.5–1.6	1.7–1.8	1.9–2.0	2.1–2.2	2.3–2.4	2.5–2.6	2.7–2.8	2.9–3.0	3.1–3.2	3.3–3.4	3.5–3.6	3.7–3.8	3.9–4.0	4.1–4.2	4.3–4.4	4.5–4.6	4.7–4.8	4.9–5.0	5.1–5.2	5.3–5.4	5.5–6.0	TOTAL
BELOW 0.8	1	2	1		1	2	1															8
0.9–1.0			3	2	4	5	3	1														18
1.1–1.2	1			3		8	5	3	4													24
1.3–1.4			1	2	2	2	6	9	6	2	2	1										33
1.5–1.6					1	2	3	10	6	5	8	4	2									41
1.7–1.8						2	2	2	4	6	4	1	2	1								24
1.9–2.0					1	1	1	1		3	7	4	3	2								23
2.1–2.2							1	1	1	3	1	2	1		1							11
2.3–2.4								1	1	1	1	1	3	3		1	1					13
2.5–2.6										1	1	1	4	1		1	1	1				11
2.7–2.8										2		1		1	1	1	1					7
2.9–3.0													3	1	2	1		1			1	9
3.1–3.2												1	2	1		1						5
3.3–3.4																				1		1
3.5–3.6															1				1			2
3.7–3.8																	1					1
TOTAL	2	2	5	7	9	22	22	28	22	23	24	16	20	10	5	5	4	2	1	1	1	231

TABLES SHOWING CORRELATION BETWEEN LENGTH OF PETIOLE & LEAF BREADTH IN GOGHARI COTTON

SEE PAGE 219 OF TEXT

CORRELATION ON THE BASIS OF THE THIRD LEAF FROM THE BASE OF THE MAIN STEM

NO OF LEAVES MEASURED, 141

BREADTH OF LEAF IN C.M.

LENGTH PETIOLE IN C.M.

to	2.3-2.4	2.7-2.8	2.9-3.0	3.1-3.2	3.3-3.4	3.5-3.6	3.7-3.8	3.9-4.0	4.1-4.2	4.3-4.4	4.5-4.6	4.7-4.8	4.9-5.0	5.1-5.2	5.3-5.4	5.5-5.6	TOTAL
BELOW 1.4	1																1
1.5-1.6	1	1					1										3
1.7-1.8					1	5	1	1									8
1.9-2.0			2	1	3	1	3	3	2								15
2.1-2.2				2	1		7	2	6	3							21
2.3-2.4					1	1	4	6	6	6	1	1					26
2.5-2.6					1		1	4	5	6	3	2	1				23
2.7-2.8							1		4	2	7	1					15
2.9-3.0						1	1		3	4		3	4	1			17
3.1-3.2									1	1	1			1		1	5
3.3-3.4													2	1	1		4
3.5-3.6												1					1
3.7-3.8													1		1		2
TOTAL	2	1	2	3	7	8	19	16	27	22	12	8	8	3	2	1	141

CORRELATION ON THE BASIS OF THE FOURTH LEAF FROM THE BASE OF THE MAIN STEM

NO OF LEAVES MEASURED, 139

BREADTH OF LEAF IN C.M.

LENGTH OF PETIOLE IN C.M.

	2.7-2.8	2.9-3.0	3.1-3.2	3.3-3.4	3.5-3.6	3.7-3.8	3.9-4.0	4.1-4.2	4.3-4.4	4.5-4.6	4.7-4.8	4.9-5.0	5.1-5.2	5.3-5.4	5.5-5.6	6.1-6.2	TOTAL
BELOW 0.8								1									1
1.3-1.4	1		1		3												5
1.5-1.6				1	2	2											5
1.7-1.8	1	1	1	3	1	1	3		2								13
1.9-2.0			2	4	2	4	2	3									17
2.1-2.2				2	6	1	2	2	5	2							20
2.3-2.4		1				2	3	6	3	4						1	20
2.5-2.6					1		3	3	6	3	2	1		1			20
2.7-2.8						1	1	3	5	5	2	3		2	1		23
2.9-3.0							1		3	1	2	1					8
3.1-3.2									1	1		1		1			4
3.3-3.4																1	1
3.7-3.8	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
TOTAL	2	2	4	10	15	11	15	18	25	16	6	6	1	5	1	2	139

CORRELATION ON THE BASIS OF THE FIFTH LEAF FROM THE BASE OF THE MAIN STEM

NO. OF LEAVES MEASURED, 116

BREADTH OF LEAF IN C.M.

LENGTH OF PETIOLE IN C.M.

to	2·1 2·2	2·5 2·6	2·7 2·8	2·9 3·0	3·1 3·2	3·3 3·4	3·5 3·6	3·7 3·8	3·9 4·0	4·1 4·2	4·3 4·4	4·5 4·6	4·7 4·8	4·9 5·0	5·1 5·2	5·3 5·4	5·5 5·6	5·7 5·8	6·8 6·4	TOTAL
BELOW 1·0	1																			1
1·3 1·4						1		1												2
1·5 1·6				2		2		1	1											6
1·7 1·8				2	1	2	2	4	1											12
1·9 2·0					1	3	2	4	2		1	1	1							15
2·1 2·2							2	2	3	4	2	1	1							15
2·3 2·4						1	2	2	1	1	6	5	1	1	1					21
2·5 2·6									1	4	3	4	4	2						18
2·7 2·8										2	3	2	1	2	2	1				13
2·9 3·0										1		1	1	2	1		1		1	8
3·1 3·2												1		2						3
3·3 3·4												1								1
3·5 3·6												1								1
TOTAL	1			4	2	9	8	14	9	12	15	17	9	9	4	1	1		1	116

TABLES SHOWING CORRELATION BETWEEN WEIGHT OF EACH SEED & OF THE LINT FROM EACH SEED ON A SINGLE PLANT

SEE PAGE 223 OF TEXT

CORRELATION IN STRAIN "B-1"

NO OF BOLLS ON PLANT, 50

WEIGHT OF SEED IN mgm.

WEIGHT OF LINT PER SEED IN mgm.

	23	25	27	29	31	33	35	37	TOTAL
67								1	1
65							2		2
63					3		1		4
67				1	1	2	1		5
59			1	2	1	2	1		7
57			1	4	3	1			9
55		1	1	2	1	2			7
53		2		5	3	1			11
51			1		1				2
49	1			1					2
TOTAL	1	3	4	15	13	8	5	1	50

CORRELATION IN STRAIN "C-1"

NO OF BOLLS ON PLANT, 47

WEIGHT OF SEED IN mgm.

WEIGHT OF LINT PER SEED IN mgm.

	39	43	45	47	49	51	53	55	57	59	61	63	65	TOTAL
17		1												1
19	1					1								2
23		2	1	1	1	1								6
25			1	1				1	1					4
27		1		2	2	1					1			7
29			1		2	1	1	2			1	1		9
31				1		3	1	3	2	2	2			14
33					1					1	1			3
35													1	1
TOTAL	1	4	3	5	6	7	2	6	3	3	5	1	1	47

CORRELATION IN STRAIN "FA-CYLINDRICAL BOLL"

NO OF BOLLS ON PLANT, 42

WEIGHT OF SEED IN mgm.

WEIGHT OF LINT PER SEED IN mgm.

	55	57	59	61	63	65	67	69	73	75	79	TOTAL
29								1				1
33		2										2
35		1										1
37		1	1	2	2							6
39	1	1	2	1		2	1					8
41			2		3		2	1	1	1	1	11
43					1		1	1		1		4
45					1			1	2			4
47								2		1	1	4
49											1	1
TOTAL	1	5	5	3	7	2	4	6	3	3	3	42

CORRELATION IN STRAIN "1A-LONG BOLL"

NO OF BOLLS ON PLANT, 26

WEIGHT OF SEED IN mgm.

WEIGHT OF LINT PER SEED IN mgm.

To	Below 47	47 50	50 53	53 56	56 59	59 62	62 65	65 68	68 71	71 74	Over 74	Total
Below-30	1											1
30-32		1	1									2
32-34				1		1						2
34-36					1							1
36-38												
38-40					1							1
40-42					1			1				2
42-44						1			1			2
44-46					2		1	1				4
46-48						1		1	1	3		6
48-50							2					2
50-52											1	1
52-54										1		1
54-56								1				1
Total	1	1	1	1	5	3	3	4	2	4	1	26

CORRELATION IN STRAIN "SELECTION 2"

NO OF BOLLS ON PLANT, 34

WEIGHT OF SEED IN mgm.

WEIGHT OF LINT PER SEED IN mgm.

	51	53	55	57	59	61	63	65	67	69	71	73	Total
33	1			1									2
35	1												1
37			1										1
39	1	1											2
41		1		1		1							3
43						1		1					2
45					2	2	1	2	1				8
47				1	1	1	1			1		2	7
49								1		1		1	3
51									1		1	2	4
53										1			1
Total	3	2	1	3	3	5	2	4	2	3	1	5	34

CORRELATION IN STRAIN "1027 A.L.F."
NO OF BOLLS ON PLANT, 44
WEIGHT OF SEED IN mgm.

WEIGHT OF LINT PER SEED IN mgm.

	29	31	33	35	37	39	41	43	45	47	49	TOTAL
45			1									1
49		2	1									3
53			1	1	1		1					4
55				1	1							2
57		1		1	1	1	1					5
59					3		1	1				5
61						2	1					3
63						1	2					3
65	1						1	1				3
67						1	1	2		2	1	7
69	1					1						2
73					1				2			3
75									1			1
77									1			1
83								1				1
TOTAL	2	3	3	3	7	6	8	5	4	2	1	44

TABLES SHOWING CORRELATION BETWEEN SEED WEIGHT AND LINT LENGTH ON A SINGLE PLANT

SEE PAGE 223 OF TEXT

CORRELATION IN STRAIN "B-1"

NO OF BOLLS ON PLANT 50

SEED WEIGHT IN mgm.

LINT LENGTH IN C.M.

	49	51	53	55	57	59	61	63	65	67	TOTAL
26	1					1					2
25			2	2		2	1	3	1		11
24		2	3		6	1	3			1	16
23			2	5	2	3		1	1		14
22	1		1		1		1				4
21			2								2
20			1								1
TOTAL	2	2	11	7	9	7	5	4	2	1	50

CORRELATION IN STRAIN "C-1"

NO OF BOLLS ON PLANT 48

SEED WEIGHT IN mgm.

LINT LENGTH IN C.M.

to	38·1 40	42·1 44	44·1 46	46·1 48	48·1 50	50·1 52	52·1 54	54·1 56	56·1 58	58·1 60	60·1 62	62·1 64	64·1 66	
=	39	43	45	47	49	51	53	55	57	59	61	63	65	TOTAL
2·3	1	1	1	1	1			1		2				8
2·4		2	2	1	3	2	1			1	1			13
2·5				2		6		2	1		2		1	14
2·6		1		1	1		1	2	2		2	1		11
2·7					1			1						2
TOTAL	1	4	3	5	6	8	2	6	3	3	5	1	1	48

CORRELATION IN STRAIN "I-A-CYLINDRICAL BOLL"

NO OF BOLLS ON PLANT 42

SEED WEIGHT IN mgm.

LINT LENGTH IN C.M.

to	54 56·0	56·1 58·0	58·1 60·0	60·1 62·0	62·1 64·0	64·1 66·0	66·1 68·0	68·1 70·0	72·1 74·0	74·1 76·0	78·1 80·0	
=	55	57	59	61	63	65	67	69	73	75	79	TOTAL
24	1	1	2				1	1				6
25			1	2				1		1		5
26		4	2		5	1		1		1	1	15
27				1	2		2	2	2		1	10
28						1		1	1			3
29							1			1	1	3
TOTAL	1	5	5	3	7	2	4	6	3	3	3	42

CORRELATION IN STRAIN "1A-LONG BOLL"

NO OF BOLLS ON PLANT 26

SEED WEIGHT IN mgm.

LINT LENGTH IN C.M.

to	BELOW 47	47 50	50 53	53 56	56 59	59 62	62 65	65 68	68 71	71 74	OVER 74	TOTAL
2·1		1										1
2·2												
2·3												
2·4					3	1	1	1				6
2·5	1		1	1	2		1	1				7
2·6						1	2	2			1	6
2·7										3		3
2·8									2			2
2·9										1		1
TOTAL	1	1	1	1	5	2	4	4	2	4	1	26

CORRELATION IN STRAIN "SELECTION 2"

NO OF BOLLS ON PLANT 34

SEED WEIGHT IN mgm.

LINT LENGTH IN C.M.

	51	53	55	57	59	61	63	65	67	69	71	73	TOTAL
20	1												1
21					1								1
22		1	1		1		1						4
23	1			1	1	2		1				1	7
24	1	1		1		1		1	1		1		7
25				1		1		1	1				4
26							1	1		1		3	6
27						1				1			2
28												1	1
29													
30										1			1
TOTAL	3	2	1	3	3	5	2	4	2	3	1	5	34

CORRELATION IN STRAIN "1027-A L F"

NO OF BOLLS ON PLANT 44

SEED WEIGHT IN mgm.

LINT LENGTH IN C.M.

	45	49	53	55	57	59	61	63	65	67	69	73	75	77	83	TOTAL
2·6				1												1
2·7	1		1	1		1	1					1				6
2·8		2	1		4	3	2	2		1						15
2·9		1	2			1		1		3		1		1		10
3·0					1				2	2	2	1				8
3·1									1	1			1			3
3·2															1	1
TOTAL	1	3	4	2	5	5	3	3	3	7	2	3	1	1	1	44